LIBRARY OF CONGRESS
00001252203

CELESTIAL SCENERY;

OR,

THE WONDERS

OF

THE PLANETARY SYSTEM DISPLAYED

ILLUSTRATING

THE PERFECTIONS OF DEITY

AND A PLURALITY OF WORLDS

BY

THOMAS DICK, LL.D.,

AUTHOR OF

"THE CHRISTIAN PHILOSOPHER," "PHILOSOPHY OF RELIGION," "PHILOSOPHY OF A FUTURE STATE," "IMPROVEMENT OF SOCIETY," "MENTAL ILLUMINATION," ETC.

NEW-YORK:

HARPER & BROTHERS, 82 CLIFF-ST

QB51
.I542
Copy 2

3
Copy......

By Transfer from
U. S. Naval Academy
Aug. 26 1932

44-30831

PREFACE.

The following work is intended for the instruction of general readers, to direct their attention to the study of the heavens, and to present to their view sublime objects of contemplation. With this view the author has avoided entering on the more abstruse and recondite portions of astronomical science, and confined his attention chiefly to the exhibition of *facts*, the foundation on which they rest, and the reasonings by which they are supported. All the prominent facts and discoveries connected with descriptive astronomy, in so far as they relate to the planetary system, are here recorded, and many of them exhibited in a new point of view; and several new facts and observations are detailed which have hitherto been either unnoticed or unrecorded.

The results of hundreds of tedious calculations have been introduced respecting the solid and superficial contents of the different planets, their satellites, and the rings of Saturn; their comparative magnitudes and motions, the extent of their orbits,

the apparent magnitudes of bodies in their respective firmaments, and many other particulars not contained in books of astronomy, in order to produce in the minds of common readers definite conceptions of the magnitude and grandeur of the solar system. The mode of determining the distances and magnitudes of the celestial bodies is explained, and rendered as perspicuous and popular as the nature of the subject will admit; and the prominent arguments which demonstrate a plural ity of worlds are considered in all their bearings, and illustrated in detail.

One new department of astronomical science, which has hitherto been overlooked, has been introduced into this volume, namely, *the scenery of the heavens as exhibited from the surfaces of the different planets and their satellites*, which forms an interesting object of contemplation, and, at the same time, a presumptive argument in favour of the doctrine of a plurality of worlds.

The author, having for many years past been a pretty constant observer of celestial phenomena, was under no necessity of adhering implicitly to the descriptions given by preceding writers, having had an opportunity of observing, through some of the best reflecting and achromatic telescopes, the greater part of the phenomena of the solar system which are here described.

Throughout the volume he has endeavoured to make the facts he describes bear upon the illustration of the Power, Wisdom, Benevolence, and the Moral Government of the Almighty, and to elevate the views of the reader to the contemplation of HIM who sits on the throne of the universe, 'by whom the worlds were framed," and who is the Source and Centre of all felicity.

In prosecuting the subject of Celestial Scenery, the author intends, in another volume, to carry forward his survey to the STARRY HEAVENS and other objects connected with astronomy. That volume will embrace discussions relative to the number, distance, and arrangement of the stars; periodical and variable stars; new and temporary stars; double and triple stars; binary systems; stellar and planetary nebulæ; the comets, and other particulars; accompanied with such reflections as the contemplation of such august objects may suggest. The subject of a plurality of worlds will likewise be prosecuted, and additional arguments, derived both from reason and Revelation, will be adduced in support of this position. The practical utility of astronomical studies, their connexion with religion, and the views they unfold of the perfections and the empire of the Creator, will also be the subject of consideration. And should the limits of a single volume permit, some hints

may be given in relation to the *desiderata* in astronomy, and the means by which the progress of the science may be promoted, together with descriptions of the telescope, the equatorial, and other instruments, and the manner of using them for celestial investigation.

Broughty Ferry, near Dundee,
December, 1837.

CONTENTS.

9. *The Planet Uranus.*

10. *The Sun.*

CHAPTER IV.

ON THE SECONDARY PLANETS.

CHAPTER V.

ON THE PERFECTIONS OF THE DEITY, AS DISPLAYED IN THE PLANETARY SYSTEM.

CHAPTER VI.

SUMMARY VIEW OF THE PLANETARY SYSTEM.

CHAPTER VII.

ON THE METHOD BY WHICH THE DISTANCES AND MAGNITUDES OF THE HEAVENLY BODIES ARE DETERMINED.

CHAPTER VIII.

ON THE SCENERY OF THE HEAVENS AS VIEWED FROM THE SURFACES OF THE DIFFERENT PLANETS AND THEIR SATELLITES.

CHAPTER IX.

ON THE DOCTRINE OF A PLURALITY OF WORLDS, WITH AN ILLUSTRATION OF SOME OF THE ARGUMENTS BY WHICH IT MAY BE SUPPORTED.

APPENDIX.

LIST OF ENGRAVINGS.

CELESTIAL SCENERY,

ETC.

INTRODUCTION.

Astronomy is that department of knowledge which has for its object to investigate the motions, the magnitudes, and distances of the heavenly bodies; the laws by which their movements are directed, and the ends they are intended to subserve in the fabric of the universe. This is a science which has in all ages engaged the attention of the poet, the philosopher, and the divine, and been the subject of their study and admiration. Kings have descended from their thrones to render it homage, and have sometimes enriched it with their labours; and humble shepherds, while watching their flocks by night, have beheld with rapture the blue vault of heaven, with its thousand shining orbs, moving in silent grandeur, till the morning star announced the approach of day. The study of this science must have been coeval with the existence of man; for there is no rational being who has for the first time lifted his eyes to the nocturnal sky, and beheld the moon walking in brightness amid the planetary orbs and the host of stars, but must have been struck with admiration and wonder at the splendid scene, and excited to inquiries into the nature and destination of those far-distant orbs. Compared with the splendour, the amplitude, the august motions, and the ideas of infinity which the celestial vault presents, the most resplendent terrestrial scenes sink into inanity, and appear unworthy of being set in competition with the glories of the sky.

When, on a clear autumnal evening, after sunset, we take a serious and attentive view of the celestial canopy; when we behold the moon displaying her brilliant crescent in the western sky; the evening star gilding the shades of night; the

planets moving in their several orbs; the stars, one after another, emerging from the blue ethereal, and gradually lighting up the firmament till it appears all over spangled with a brilliant assemblage of shining orbs; and particularly when we behold one cluster of stars gradually descending below the *western* horizon, and other clusters emerging from the *east*, and ascending, in unison, the canopy of heaven; when we contemplate the whole celestial vault, with all the shining orbs it contains, moving in silent grandeur, like one vast concave sphere, around this lower world and the place on which we stand—such a scene naturally leads a reflecting mind to such inquiries as these: Whence come those stars which are ascending from the east? Whither have those gone which have disappeared in the west? What becomes of the stars during the day which are seen in the night? Is the motion which appears in the celestial vault *real*, or does a motion in the earth itself cause this appearance? What are those immense numbers of shining orbs which appear in every part of the sky? Are they mere studs or tapers fixed in the arch of heaven, or are they bodies of immense size and splendour? Do they shine with borrowed light, or with their own native lustre? Are they placed only a few miles above the region of the clouds, or at immense distances, beyond the range of human comprehension? Can their distance be ascertained? Can their bulk be computed? By what laws are their motions regulated? and what purposes are they destined to subserve in the great plan of the universe? These, and similar questions, it is the great object of astronomy to resolve, in so far as the human mind has been enabled to prosecute the path of discovery.

For a long period, during the infancy of science, comparatively little was known of the heavenly bodies excepting their apparent motions and aspects. Instead of investigating with care their true motions, and relative distances and magnitudes, many of our ancestors looked up to the sky either with a brute unconscious gaze, or viewed the heavens as the book of fate in which they might read their future fortunes, and learn, from the signs of the zodiac, and the conjunctions and other aspects of the planets, the temperaments and destinies of men and the fate of empires. And even to this day, in many countries, the fallacious art of prognosticating fortunes by the stars is one of the chief uses to which the science of the heavens

is applied. In the ages to which I allude, the world in which we dwell was considered as the largest body in the universe. It was supposed to be an immense plane, diversified with a few inequalities, and stretching in every direction to an indefinite extent. How the sun penetrated or surmounted this immense mass of matter every morning, and what became of him in the evening—whether, as the poets assert, he extinguished himself in the western ocean, and was again lighted up in the eastern sky in the morning—many of them could not determine. *Below* this mass of matter we call the earth, it was conceived that nothing but darkness and empty space, or the regions of Tartarus, could exist. The stars which gild the concave of the firmament *above* were considered only as so many bright studs fixed in a crystalline sphere, which carried them round every day to emit a few glimmering rays, and to adorn the ceiling of our terrestrial habitation. Above the visible firmament of heaven, and far beyond the ken of mortal eye, the Deity was supposed to have fixed his special residence, among myriads of superior intelligences. The happiness, the preservation, and the moral government of the human race were supposed to be the chief business and object of the Deity, to which all his decrees in eternity past, and all his arrangements in relation to eternity to come, had a special and almost exclusive reference. Such ideas are still to be found, even in the writings of Christian divines, at a period no farther back than the sixteenth century.

To hazard the opinion that the plans of the Almighty embraced a much more extensive range—that other beings, analogous to men, inhabited the planetary or the starry orbs, and that such beings form by far the greater part of the population of the universe—would have been considered a heresy in religion, and would probably have subjected some of those who embraced it to the anathemas of the church, as happened to Spigelius, bishop of Upsal, for defending the doctrine of the antipodes, and to Galileo, the philosopher of Tuscany, for asserting the motion of the earth. The ignorance, the intolerance, and the contracted views to which I allude, are, however, now, in a great measure, dissipated. The light of science has arisen, and shed its benign influence on the world. It has dispelled the darkness of former ages, extended our prospects of the grandeur and magnificence of the scene of creation, and, in conjunction with the discoveries of revela-

tion, has opened new views of the perfections and moral government of the Almighty. In the progress of astronomical science, the distances and magnitudes of many of the celestial bodies began to be pretty nearly ascertained; and the invention of the *telescope* enabled the astronomer to extend his views into regions far beyond the limits of the unassisted eye, and to discover myriads of magnificent globes formerly hid in the unexplored regions of immensity. The planetary orbs were found to bear a certain resemblance to the earth, having spots and dark streaks of different shades upon their surfaces; and it was not long in being discovered that, notwithstanding their apparent brilliancy, they are, in reality, opaque globes, which derive all their light and lustre from the sun. The planet Venus, in different parts of its orbit, was observed to exhibit a gibbous phase, and the form of a crescent similar to the moon, plainly indicating that it is a dark globe, enlightened only on one side by the rays of the sun. The moon was perceived to be diversified with hills and valleys, caverns, rocks, and plains, and ranges of mountains of every shape, but arranged in a manner altogether different from what takes place in our sublunary sphere. The sun, which was generally supposed to be a ball of liquid fire, was found to be sometimes covered with large dark spots, some of them exceeding in size the whole surface of the terraqueous globe, and giving indications, by their frequent changes and disappearance, of vast operations being carried on upon the surface and in the interior of that magnificent luminary. Hundreds of stars were descried where scarcely one could be perceived by a common observer; and as the powers of the telescope were increased, thousands more were brought to view, extending in every direction, from the limits of unassisted vision throughout the boundless extent of space.

It is natural for an intelligent observer of the universe to inquire into the final causes of the various objects which exist around him. When he beholds the celestial regions filled with bodies of an immense size, arranged in beautiful and harmonious order, and performing their various revolutions with regularity and precision, the natural inquiry is, For what end has the Deity thus exerted his wisdom and omnipotence? What is the ultimate destination of those huge globes which appear in the spaces of the firmament? Are these vast masses of matter suspended in the vault of heaven merely to diversify

the voids of infinite space, or to gratify a few hundreds of terrestrial astronomers in peeping at them through their glasses? Is the Almighty to be considered as taking pleasure in beholding a number of splendid lamps, hung up throughout the wilds of immensity, which have no relation to the accommodation and happiness of intelligent minds? Has he no end in view corresponding to the magnificence and grandeur of the means he has employed? Or, are we to conclude that his wisdom and goodness are no less conspicuously displayed than his omnipotence in peopling those vast bodies with myriads of intelligent existences of various orders, to share in his beneficence and to adore his perfections? This last deduction is the only one which appears compatible with any rational ideas we can entertain of the wisdom and intelligence of the Eternal Mind, and the principles of the Divine government.

This opinion is now very generally entertained by those who have turned their attention to the subject. But it is frequently admitted on grounds that are too general and vague; on the authority of men of science, or on the mere ground that the planets and stars are bodies of immense size; and hence it is only considered as a *probable* opinion, and *a thorough conviction* of its truth is seldom produced in the mind.

In the following work it shall be our endeavour to show that the arguments which may be brought forward to establish the doctrine of a plurality of worlds have all the force of a *moral demonstration;* that they throw a lustre on the perfections of the Divinity; and that the opposite opinion is utterly inconsistent with every idea we ought to entertain of an All-wise and Omnipotent Intelligence.

In order to the full illustration of this subject, it will be necessary to take a pretty minute and comprehensive view of all the known facts in relation to the heavenly bodies; and while these facts will be made to bear upon the object now proposed, they will likewise tend to exhibit the scenery of the heavens, and to elucidate many of the prominent truths and principles connected with descriptive astronomy. In the progress of our discussions, we shall descend into many minute particulars which are generally overlooked by writers on the subject of astronomy, and shall introduce several original observations and views on this subject which have not hitherto been particularly detailed

CHAPTER I.

ON THE GENERAL APPEARANCE AND APPARENT MOTIONS OF THE STARRY HEAVENS.

Before proceeding to a particular description of the real magnitudes, motions, and phenomena of the heavenly bodies, it may not be improper to take a brief survey of the general appearance and apparent motions of the celestial vault, as they present themselves to the eye of a common observer.

It is of importance to every one who wishes to acquire a clear idea of the principles of astronomy and the phenomena of the heavens, that he contemplate with his own eyes the *apparent* aspects and revolutions of the celestial bodies before he proceeds to an investigation of the *real* motions, phenomena, and arrangements which the discoveries of science have led us to deduce. From want of attention to this circumstance, there are thousands of smatterers in the science of astronomy who never acquire any clear or comprehensive ideas on this subject; and who, instead of clearly perceiving the relations of the heavenly orbs from their own observation, rely chiefly on the assertions of their instructers, or the vague descriptions to be found in elementary books. It is amazing how many intelligent men there are among us who would not wish to be considered altogether ignorant of modern astronomy, yet have never looked up to the celestial vault with fixed attention; have never made repeated observations to discover its phenomena; and cannot tell, from their own survey, what are the various motions it exhibits. There are thousands and ten thousands who have gazed on a clear evening sky, at certain intervals, during a period of many years, yet can tell no more about the glorious scene around them than that they behold a number of shining points twinkling in every direction in the canopy above. Whether these bodies shift their positions with regard to each other, or remain at the same relative distances; whether any of them appear in motion, while others appear at rest; whether the whole celestial canopy appears to stand still, or is carried round with some general motion;

whether all the stars which are seen at six o'clock in the evening are also visible at twelve at midnight; whether the stars rise and set, as the sun and moon appear to do; whether they rise in the east, or northeast, or in any other quarter; whether some rise and set regularly, while others never descend below the horizon; whether any particular stars are occasionally moving backward or forward, and in what parts of the heavens they appear; whether there are stars in our sky in the daytime as well as during night; whether the same clusters of stars are to be seen in summer as in winter? To these and similar questions there are multitudes who have received a regular education, and are members of a Christian church, who could give no satisfactory answers. And yet almost every one of these inquiries could be satisfactorily answered, in the course of a few evenings, by any man of common understanding who directed his attention for a few hours to the subject, and that, too, without the knowledge of a single scientific principle. He has only to open his eyes, and to make a proper use of them; to fix his attention on the objects before him; to make one observation after another, and compare them together; and to consider that "the works of the Lord are *great*," and that they ought "to be sought out (or seriously investigated) by all those who have pleasure therein."

If this representation be admitted as just, what a striking idea does it present of the *apathy* and indifference of the greater part of mankind in regard to the most astonishing and magnificent display which the Creator has given of himself in his works! Had we an adequate conception of all the scenes of grandeur, and the displays of intelligence and omnipotent power, which a serious contemplation of a starry sky is calculated to convey, all the kingdoms of this world would sink into comparative insignificance, and all their pomp and splendour appear as empty as the bubbles of the deep. It is amazing that *Christians*, in particular, should, in so many instances, be found overlooking such striking displays of Divine perfection as the firmament opens to our view, as if the most august works of the Creator, and the most striking demonstration of his "eternal power and godhead," were unworthy of their regard; while we are commanded, in scripture, to "lift up our eyes on high, and consider Him who hath created these orbs, who bringeth forth their hosts by number," and who guides them in all their motions "by the greatness of his

strength." "The heavens," says the psalmist, "declare the glory of the Lord, and the firmament showeth his handiwork." Though these luminaries "have no speech nor language," though "their voice is not heard" in articulate sounds, yet, as they move along in *silent* grandeur, they declare to every reflecting beholder that "the hand that made them is Divine."

One great cause of this indifference and inattention is to be found in the want of those habits of observation and reflection which ought to be formed in early life by the instructions imparted in the family circle and at public seminaries. Children, at a very early age, are endowed with the principle of curiosity, and manifest an eager desire to become acquainted with the properties and movements of the various objects which surround them; but their curiosity is, in most instances, improperly directed; they are seldom taught to make a right use of their senses; and when they make inquiries in reference to the appearances of nature, their curiosity is too frequently repressed, till, at length, habits of inattention and indifference take possession of their minds. A celebrated author represents his pupil as expressing himself in the following manner:—"I shall freely tell you the things which frequently occur to my mind, and often perplex my thoughts. I see the heavens over my head, and tread on the earth with my feet; but I am at a loss what to think of that *mighty concave* above me, or even of this very earth I walk upon. I often think whether the earth may not stretch out in breadth to immensity, so as, if one was to travel it over, one should never be able to get to the *end* of the earth, but always find room to continue the journey; nor can I satisfy myself as to the depth of the earth, whether it has any bottom; and, if so, what it can be that is below the earth. As to the heaven, I need say nothing: every change that happens, and every object seen there, perplex me with doubts and fruitless guesses. I often wonder how the sun moves over so large a space every day, and yet seems not to stir out of his place. I would know where he goes beyond the mountains in the evening; what becomes of him in the nighttime; whether he makes his way through the thickness of the earth, or the depth of the sea, and so always shows himself again from the east next morning. It seems strange that, being so small a body as he is, he should still be seen everywhere, and still of the same

bigness. The various nature ot the *moon* seems yet more perplexing; to-night, perhaps, you can scarce discern her; but, in a few days, she becomes larger than the body of the sun itself. In a little time after she decays, and, at last, wears quite away; yet she recovers again. In a word, she is never the same, and yet still becoming what she was before. What means that multitude of stars scattered over the face of the whole sky, whose number is so great that it is become proverbial? There are other things I want to be informed of, but these are the main difficulties which exercise my thoughts and perplex my mind with endless doubting."

Were the young, or any other class of persons, led to such reflections as these, and were their doubts and inquiries resolved, so far as our knowledge extends, we should have a hundred intelligent observers of the phenomena of the universe for one that is found in the present state of society. But, instead of answering their inquiries and gratifying their natural curiosity, we not unfrequently tell them that they are troublesome with their idle questions; that they ought to mind their grammar and parts of speech, and not meddle with philosophical matters till they be many years older; that such subjects cannot be understood till they become men; and that they must be content to remain in ignorance for ten or twelve years to come. Thus we frequently display our own ignorance and inattention, and thus we repress the natural desire for knowledge in the young, till they become habituated to ignorance, and till the uneasy sense arising from curiosity and unsatisfied desire has lost its edge, and a desire for sensual or vicious pleasure usurps its place. I recollect, when a boy of about seven or eight years of age, frequently musing on such subjects as those to which we have now alluded. I sometimes looked out from a window, in the daytime, with fixed attention, on a pure azure sky, and sometimes stretched myself on my back on a meadow, or in a garden, and looked up to the zenith to contemplate the blue ethereal. On such occasions a variety of strange ideas sometimes passed through my mind. I wondered how far the blue vault of heaven might extend; whether it was a solid transparent arch, or empty space; what would be seen could I transport myself to the highest point I perceived; and what display the Almighty made of himself in those regions so far removed from mortal view. I asked myself whether the heavens might be bounded

on all sides by a solid wall; how far this wall might extend in thickness; or whether there was nothing but empty space, suppose we could fly for ever in any direction. I then entered into a train of inquiries as to what would have been the consequences had neither heaven nor earth been made, and had God alone existed in the boundless void. Why was the world created? What necessity was there why God himself should exist? And why was not all one vast blank, devoid of matter and intelligence? My thoughts ran into wild confusion; they were overwhelming, and they became even oppressive and painful, so as to induce me to put a check to them, and to hasten to my playful associates and amusements. But although my relatives were more intelligent than many of their neighbours, I never thought of broaching such ideas, or of making any inquiries of them respecting the objects which had perplexed my thoughts; and, even if I had, it is not likely I should have received much satisfaction. Such views and reflections are, perhaps, not uncommon in the case of thousands of young people. I mention these things to show that the youthful mind, in consequence of the innate desire of knowledge with which it is endowed, is often in a state peculiarly adapted for receiving instruction on many important subjects, and for becoming an intelligent observer of the economy of nature, were it not that our methods of instruction hitherto, both in public and in private, instead of gratifying juvenile curiosity, have frequently tended to counteract the natural aspirations of the opening mind.

But, leaving such reflections and digressions, let us now take a general view of the motions and phenomena of the nocturnal heavens.

Let us suppose ourselves under the open canopy of heaven in a clear night, at six o'clock in the evening, about the first of November. I fix upon this period, because the *Pleiades*, or seven stars, which are known to every one, are then visible during the whole night, and because, at this season of the year, the most brilliant fixed stars, and the more remarkable constellations, are above the horizon in the evening. Turning our eyes, in the first place, towards the *eastern* quarter of the heavens, we shall see the seven stars just risen above the horizon, in a direction about half way between the east and the northeast points, or east-northeast. Northwest from the seven stars, at the distance of thirty degrees, a very bright star, named *Capella*, may be perceived at

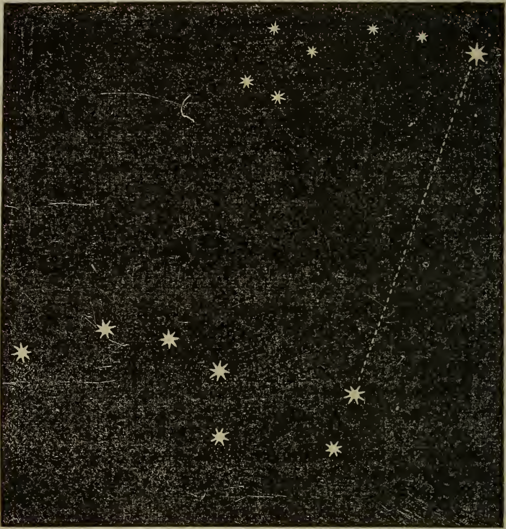
an elevation of about eighteen degrees above the horizon. Directing our view towards the south, we shall perceive a pretty bright star, with a small star on the north and another on the south of it, which has just passed the meridian. This star is called *Altair*, and belongs to the constellation *Aquila*. It is nearly south, at an elevation of forty-six degrees, or about half way between the horizon and the zenith. About thirty-three degrees north from Altair, and a little farther to the west, is the brilliant star *Lyra*, belonging to the *Harp*. Looking to the west, a bright star, named *Arcturus*, will be seen about fifteen degrees above the horizon, a very little to the north of the western point. Turning our eyes in a northerly direction, the constellation *Ursa Major*, or the Great Bear, presents itself to view. This cluster of stars is sometimes distinguished by the name of the *Plough*, or *Charles's Wain*, and is known to almost every observer. The relative positions of the prominent stars it contains are represented in the following figure. At the time of the evening now supposed, it appears a little to the westward of the northern point of the heavens, the two eastern stars of the square being about eighteen degrees west from that point. These two stars, the uppermost of which is named *Dubhe*, and the lower one *Merak*, are generally distinguished by the name of the *Pointers*, because they *point*, or direct our eye towards the pole-star.

The seven stars in the lower part of the figure are the prominent stars which constitute the tail and the body of the Great Bear. The first of these, reckoning from the left, is termed *Benetnach*, the second *Mizar*, the third *Alioth*, the fourth *Megrez*, immediately below which is *Phad*. The other two stars to the right are the *Pointers* alluded to above. If a line connecting these two stars be considered as prolonged upward to a considerable distance till it meet the first bright star, it directs us to the *pole-star*, which is the one nearest to the pole, and which, to a common observer, never seems to shift its position. The uppermost star in the figure towards the right hand represents the pole-star in its relative distance and position to the Great Bear. The distance between the two pointers, Dubhe and Merak, is about five degrees; and the distance between Dubhe, the uppermost of the pointers, and the pole-star, is about twenty-nine degrees; so that the space between Dubhe and the pole-star is nearly six times the distance between the two pointers. By attending to these cir-

FIG. I.

North.

West.



East.

cumstances, the distance between any two stars, when expressed in degrees, may be nearly ascertained by the eye. The six small stars in the upper part of the figure represent the constellation *Ursa Minor*, or the Lesser Bear, of which the pole-star forms the tip of the tail. They resemble the configuration of the stars in the Great Bear, only they are on a smaller scale, and in a reversed position.*

* In these observations, the observer is supposed to be placed nearly in 52° north latitude, which is nearly the latitude of London. Those who reside in latitudes between 40° and 45°, as the inhabitants of Philadelphia, New-York, Hartford, Boston, Montreal, Madrid, Rome, &c., would require to postpone their observations till a little after half past six in the evening, and to make a small allowance for the elevations, above stated, of certain stars above the horizon. In most other respects,

Having now fixed on certain stars or points in the heavens as they appear about six in the evening, and marked their relative positions, let us take another view of the celestial vault as it appears about ten o'clock the same evening, or the first clear evening afterward. We shall then find that the seven stars have risen to a considerable elevation, and are nearly half way between the eastern horizon and the south; that the *Bull's-eye*, a bright, ruddy star, which was before invisible, is now seen a little to the eastward of the Pleiades; and that the brilliant constellation *Orion*, which in the former observation was below the horizon, is now distinctly visible in the east and southeast; and the star *Capella* midway between the horizon and the zenith. The stars *Altair* and *Lyra*, which were before nearly south, have descended more than half way towards the western horizon. The star Arcturus is no longer visible, having sunk beneath the horizon; and many stars in the eastern quarter of the heavens, which were formerly unseen, now make their appearance at different elevations. The stars of the Great Bear, particularly the two pointers, which were formerly to the west of the north point, have now passed to the east of it. At twelve o'clock, midnight, their position may be thus represented. (See *Fig.* II.)

The pointers now appear considerably to the eastward of the north point, and considerably more elevated than before, while the stars in the tail appear much lower. About three o'clock next morning the pointers will appear nearly due east from the pole-star, and at the same elevation above the horizon; and the other stars in that constellation will be seen hanging, as it were, nearly perpendicular below them. At this hour the Pleiades, or seven stars, will appear to have moved twenty-five degrees past the meridian to the west, and the brilliant constellation Orion will be seen nearly due south. The bright star Capella now appears nearly in the zenith, or point directly over our heads; Lyra is in the horizon, nearly due north, and Altair has descended below the western horizon. At six in the morning, the seven stars will be seen in the west, only a short distance above the horizon; and all the other stars to the eastward of them will be found to have made a considerable progress towards the west. At this hour the

the appearance of the heavens, to the inhabitants of such places, will be the same as here described.

Fig. II.

North.

West.

East.

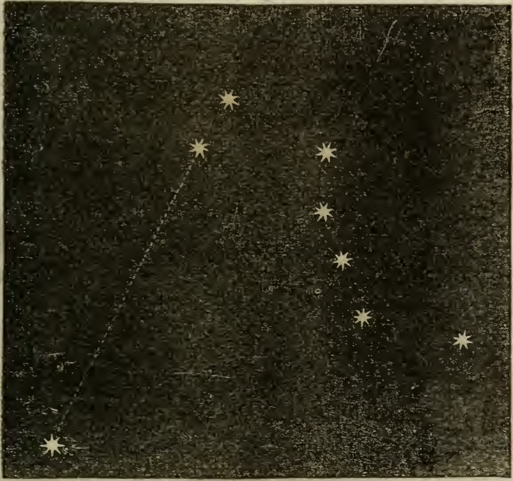
stars of the Great Bear will appear near the upper part of the heavens, and the pointers not far from the zenith. Their position at this time is shown in the following figure. (See *Fig.* III.)

Here the pointers appear elevated a great way *above* the pole-star, whereas, in the observation at six in the evening, the whole constellation appeared far *below* it. At eight in the morning, the whole of the constellation would be seen nearly overhead, were the stars then visible; at twelve, noon, it would appear towards the west, at a considerable elevation; and at six in the evening it would again return to its former position, as noted in our first observation. The

FIG. III.

North.

West.

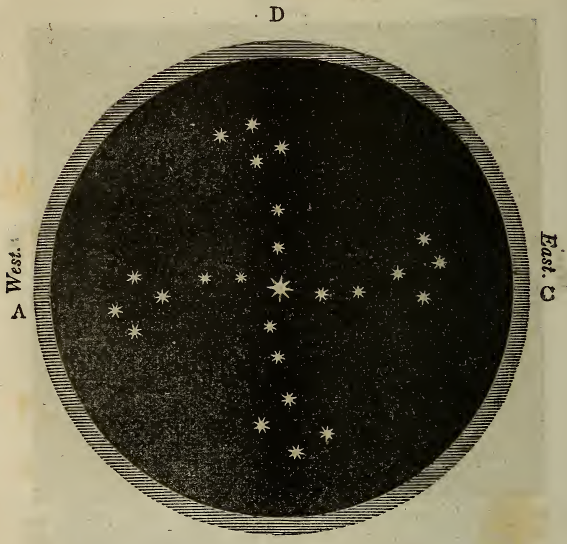


East

following figure represents the position of *Ursa Minor*, or the Lesser Bear, at four different periods during twenty-four hours. (See *Fig.* IV.)

At six in the evening, about the beginning of November, *Ursa Minor* will be nearly in the position represented on the left at *A*, nearly straight west from the pole-star, which appears in the centre. Six hours afterward, or at twelve, midnight, it will appear below the pole, in the position marked *B*; at six next morning it will appear opposite to its first position, as represented on the right at *C*; at twelve, noon, it will appear above the pole, as represented at *D*; but in this position it cannot be seen in November, or during the winter months, as the stars at that time of the day are eclipsed by the light of the sun. At six in the evening it again returns to its former position. Such are the general appearance and apparent motions of all the stars in the northern hemisphere, within

FIG. IV.



fifty-two degrees of the pole, to a spectator situated in 52° of north latitude. They all appear to perform a circuit, in the course of twenty-four hours, around a point which is the centre of their motion, near to which is the pole-star. All the stars within this range never set, but appear to describe complete circles, of different dimensions, around the pole and above the horizon. When they are in the lower part of their course, or beneath the pole, they appear to move from west to east; but when in the higher part of their course, their apparent motion is from east to west; and all their circuits are completed in exactly the same period of time, namely, twenty-three hours, fifty-six minutes, and four seconds.

Let us now consider the appearances which present them

selves in other quarters of the heavens. If we turn our eyes a little to the left of the south, near to that point of the compass called south-southeast, and observe a star near the horizon, such as the star *Fomalhaut*, in the Southern Fish, it will appear to rise to a very small altitude when it comes to the meridian, only about six degrees, and in about five hours it will set near the point south-southwest, having described a very small arc of a circle above the horizon. If we direct our attention to the southeast, and observe any bright star, such as Sirius, or the Dog-star, in the horizon, it will make a larger circuit over the southern sky, and will remain about nine hours above the horizon before it sets in the southwest. If we look due east, and see a star, such as Procyon in the constellation of the Lesser Dog, rising, it will remain about twelve hours above the horizon, and will set in the west. If we look to the northeast, and perceive any stars, such as *Castor* and *Pollux*, beginning to appear, they will make a large circuit round the heavens, such as the sun describes in the month of June, and, after the period of about eighteen hours, will set in the northwest.

Such are the general appearances and the apparent motions of the heavens which present themselves when viewed from our northern latitude. Were we to take our station near the Gulf of Guinea, in the island of Sumatra or Borneo, in the Gallipago Isles, in the city of Quito in South America, or on any other point of the globe near the equator, the motions of the stars would appear somewhat different. The pole-star, instead of being at a high elevation, as in our latitude, would be in the horizon. All the stars would appear to rise and set, and the time of their continuance above the horizon would be precisely the same. The stars which rise in the east would ascend to the zenith, and pass directly overhead, in the course of six hours; and in another six hours they would descend to the horizon, and set in the western point. The stars near the northern and southern points would appear to describe small semicircles above the horizon during the same time, and their motion would appear much slower. The Great Bear, which never sets in our latitude, would be above the horizon only during the one half of its circuit. Many stars and constellations would appear in the southern quarter of the sky which we never see in our latitude. Every star would be found to remain exactly twelve hours above and twelve hours below the

horizon, and all the visible stars in the firmament might, from such a position, be perceived in the course of a year. Were we to take our station in the southern hemisphere, in Valdivia, Botany Bay, or Van Diemen's Land, the heavens would present a different aspect from any of those we have yet contemplated. The north pole-star, the Great Bear, and other neighbouring constellations, would never appear above the horizon. Many of the stars which we now see in the south would appear in the north. The south pole would appear elevated about forty degrees above the horizon, and various clusters of stars would be seen revolving round it, as the Great Bear and other constellations do around the north pole. In fine, could we take our station at ninety degrees of north latitude, or, in other words, at the north pole of the world, we should just see one half of the stars of heaven, and no portion of the other half would ever be visible. These stars would appear neither to rise nor set, nor yet to stand still. They would appear to move round the whole heavens, in circles parallel to the horizon, every twenty-four hours; and on every clear evening all the stars that are ever visible in that hemisphere may be seen. The stars, however, that appear in a certain direction at any particular hour will appear at the same elevation in the opposite direction twelve hours afterward; and during nearly six months no stars will be seen in the sky.

The apparent motion of the heavens may at any time be perceived by fixing on any star that appears nearly in a line with a tree, a spire, or any other fixed object, and in the course of a few minutes its motion will be perceptible; or, fix a common telescope upon a pedestal, and direct it to any star, and in three or four minutes it will be seen to have passed out of the field of view. In the descriptions now given, I have spoken of the *pole-star* as if it were actually the pole, or the most northerly point of the heavens. But it may be proper to state, that though it is the nearest large star to that point, it is not actually in the pole; it is somewhat more than a degree and a half from the polar point, and revolves around that point, in a small circle, every twenty-four hours. This motion may be perceived by directing a telescope of a moderate magnifying power to this star, and fixing it in that position, when, in the course of an hour or two, it will be found to have moved beyond the field of view.

All the observations above stated (excepting those supposed

to have been made at the equator, and in southern latitudes) may be accomplished in the course of two or three evenings, without incurring the loss of a couple of hours; for each observation may be made in the space of five or ten minutes. Every inhabitant of the globe has an opportunity, if he choose, of observing the aspect of the heavens in the manner now described, excepting, perhaps, those who live in dark and narrow lanes, in large cities, where the sky is scarcely visible; the most unnatural situations in which human beings can be placed, and which ought no longer to remain as the abodes of men. And the man who will not give himself the trouble of making such observations on the starry heavens deserves to remain in ignorance of the most sublime operations of the Creator.

Let us now consider what is the conclusion we ought to deduce from our observations respecting the apparent motion of the heavens. All the phenomena which we have described, when duly considered and compared together, conspire to show that *the whole celestial vault performs an apparent revolution round the earth*, carrying, as it were, all the stars along with it, in the space of twenty-four hours. This may be plainly demonstrated by means of a celestial globe, on which all the visible stars are depicted. When the north pole is elevated fifty-two degrees above the northern horizon, and the globe turned round on its axis, all the variety of phenomena formerly described may be clearly perceived.

Here, then, we have presented to view a scene the most magnificent and sublime. All the bright luminaries of the firmament revolving in silent grandeur around our world; not only the stars visible to the unassisted eye, but all the ten thousands and millions of stars which the telescope has enabled us to descry in every region of the heavens, for they all seem to partake of the same general motion. If we could suppose this motion to be *real*, it would convey to the mind the most magnificent and impressive idea which could possibly be formed of the incomprehensible energies of Omnipotence. For here we have presented to view, not only ten thousand times ten thousands of immense globes, far superior to the whole earth in magnitude, but the greater part of them carried round in their revolutions with a velocity that baffles the power of the most capacious mind to conceive. In this case, there would be millions of those vast luminaries, which behooved to

move at the rate of several thousands of millions of miles *in the space of a second of time.* For in proportion to the distances of any of these bodies would be the rapidity of their motions. The nearest star would move more than fourteen hundred millions of miles during the time in which the pendulum of a clock moves from one side to another ; but there are thousands of stars visible through our telescopes at least a hundred times more distant, and whose distance cannot be less than 2,000,000,000,000,000, or two thousand billions of miles. This forms the radius, or half diameter of a circle whose circumference is about 12,500,000,000,000,000, or twelve thousand five hundred billions of miles. Around this circumference, therefore, the star behooved to move every day. In a siderial day of twenty-three hours, fifty-six minutes, and four seconds, there are 86,164 seconds. Divide the number of miles in the circumference by the number of seconds in a day, and the quotient will be somewhat more than 145,000,000,000, or one hundred and forty-five thousand millions, which is the number of miles that such a star would move in the space of a second, or during the pulsation of an artery, were the celestial vault to be considered as really in motion ; a rate of motion more than a hundred thousand millions of times greater than that of a cannon ball, and seven hundred thousand times more rapid than the motion of light itself, which is considered the swiftest motion in nature.

The idea of such astonishing velocities completely overpowers the human imagination, and is absolutely inconceivable. We perceive no objects or motions connected with our globe that can assist our imagination in forming any definite conceptions on this subject. The swiftest impulse that was ever given to a cannon ball, or any other projectile, sinks into nothing in the comparison. Were we transported to the planet Saturn, and placed on its equatorial regions, we should behold a stupendous arch, thirty thousand miles in breadth, and more than six hundred thousand miles in circumference, revolving around us every ten hours, at the rate of a thousand miles in a minute, and sixty thousand miles every hour. But even this astonishingly rapid motion would afford us little assistance in forming our conceptions, as it bears no comparison with the motions to which we have now adverted. It becomes those persons, therefore, who refuse to admit the motion of the earth, to consider, and to ponder with attention, the only other al-

ternative which *must be* admitted, namely, that all the bodies of the firmament move round the earth every day with such amazing velocities as have now been stated. If it appear wonderful that this globe of land and water, with all its mighty cities and vast population, moves round its axis every day at the rate of a thousand miles an hour, how much more wonderful, and passing all comprehension, that myriads of huge globes should move round the earth in the same time with such inconceivable rapidity. If we reject the motion of the earth because it is incomprehensible and contrary to all our preconceived notions, we must, on the same ground, likewise reject the motion of the heavens, which is far more difficult to be conceived, and consequently fall into downright skepticism, and reject even the evidence of our senses as to what appears in the economy of nature. Such views and considerations, however, teach us that, in whatever point of view we contemplate the works of the Almighty, particularly the scenery of the heavens, the mind is irresistibly inspired with sentiments of admiration and wonder. To the vulgar eye as well as to the philosophic, "the heavens declare the glory of God." Their harmony and order evince his wisdom and intelligence; and the numerous bodies they contain, and the astonishing motions they exhibit, on whatever hypothesis they are contemplated, demonstrate both to the savage and the sage the existence of a power which no created being can control.

"View the amazing canopy!
The wide, the wonderful expanse!
Let each bold infidel agree
That God is there, unknown to chance."

We cannot, however, admit, in consistency with the dictates of enlightened reason, that the apparent diurnal movements of the stars are the *real* motions with which these bodies are impelled. For, in the first place, *such motions are altogether unnecessary* to produce the effect intended, namely, the alternate succession of day and night with respect to our globe; and we know that the Almighty does nothing in vain, but employs the most simple means to accomplish the most astonishing and important ends. The succession of day and night can be accomplished by a simple rotation of the earth from west to east every twenty-four hours, which will completely account for the apparent motion of the heavens, in the

same time, from east to west. This we find to be the case with Jupiter and Saturn, which are a thousand times larger than the earth, as well as with the other planets, which have a rotation round their axes, some in ten hours, some in twenty-three, and some in ten hours and a half; and, consequently, from the surfaces of these bodies the heavens *will appear* to revolve around them in another direction from what they do to us, and, in certain instances, with a much greater degree of velocity. We must therefore conclude that our motion every day towards the east causes the heavens to appear as if they moved towards the west; just as the trees and houses on the side of a narrow river appear to move to the west when we are sailing down its current in a steamboat towards the east.

2. *Because it is impossible to conceive that so many bodies of different magnitudes, and at different distances from the earth, could all have the same period of diurnal revolution.* The sun is four hundred times farther from us than the moon. and is sixty millions of times larger. Saturn and Herschel are still farther from the earth; the comets are of different sizes, and traverse the heavens in all directions and at different distances; the fixed stars are evidently placed at different distances from the earth and from each other; yet all these bodies have exactly the same period of revolution, even to a single moment, if the heavens revolve around the earth. and that, too, notwithstanding the other motions, in various directions, which many of them perform. It is, therefore, much more natural and reasonable to suppose that the earth revolves around its axis, since this circumstance solves all the phenomena and removes every difficulty.

3. Because *such a rate of motion in the heavenly bodies*, if it could be supposed to exist, *would soon shatter them to atoms.* Were a ball of wood to be projected from a cannon at the rate of a thousand miles an hour, in a few moments it would be reduced to splinters; and hence the forage and other soft substances projected from a musket or a piece of ordnance are instantly torn to pieces. What, then, might be supposed to be the consequence, were a body impelled through the regions of space with a velocity of a hundred and forty thousand millions of miles in a moment of time? It would most assuredly reduce to atoms the most compact bodies in the universe, although they were composed of sub-

stances harder than adamant. But as the fixed stars appear to be bodies of a nature somewhat similar to the sun, and as the sun is much less dense than the earth, and only a little denser than water, it is evident that they could not withstand such a rapidity of motion, which would instantly shatter their constitution, and dissipate every portion of their substance through the voids of space.

4. Because *there is no instance known in the universe* (if that to which we are now adverting be excepted) *of a larger body revolving around a smaller.* The planet Jupiter does not revolve around his satellites, which are a thousand times less than that ponderous globe, but they all revolve around him; nor does the earth, which is fifty times larger than the moon, revolve around that nocturnal luminary, but she regularly revolves about the earth, as the more immediate centre of her motion. The sun does not perform his revolution around Venus or Mercury, but these planets, which are small compared with that mighty orb, continually revolve about him as the centre of their motions. Neither on earth nor in the heavens is there an instance to be found contrary to this law, which appears to pervade the whole system of universal nature; but if the diurnal revolution of the stars is to be considered as their proper motion, then the whole universe, with all the myriads of huge globes it contains, is to be considered as daily revolving around an inconsiderable ball, which, when compared with these luminaries, is only as an atom to the sun, or as the smallest particle of vapour to the vast ocean.

5. The apparent motion of the heavens cannot be admitted as *real, because it would confound all our ideas of the intelligence of the Deity.* While it tended to exalt our conceptions of his omnipotence to the highest pitch, it would convey to us a most unworthy and distorted idea of his *wisdom.* Wisdom is that perfection of an intelligent agent which enables him to proportionate one thing to another, and to devise the most proper *means* in order to accomplish important *ends.* We infer that an artist is a wise man from the nature of his workmanship, and the methods he employs to accomplish his purposes. We should reckon that person foolish in the extreme who should construct, at a great expense, a huge and clumsy piece of machinery for carrying round a grate, and the wall of a house to which it is attached, for the purpose of roasting a small fowl placed in the centre of its motion, instead of making

the fowl turn round its different sides to the fire. We should consider it as the most preposterous project that ever was devised were a community to attempt, by machinery, to make a town and its harbour move forward to meet every boat and small vessel that entered the river on which it was situated, instead of allowing such vehicles to move onward as they do at present. But none of these schemes would be half so preposterous as to suppose that the vast universe moves daily round an inconsiderable ball, when no end is accomplished by such a revolution but what may be effected in the most simple manner. Such a device, therefore, cannot be any part of the arrangements of Infinite Wisdom. It would tend to lessen our ideas of the *intelligence* of that adorable Being who is "wonderful in counsel and excellent in working," who "established the world by his wisdom, and stretched out the heavens by his understanding," and whose wisdom as far excels that of man as the "heaven in its height surpasses the earth." This argument alone I consider as demonstrative of the position we are now attempting to support.

The above are a few arguments which, when properly weighed, ought to carry conviction to the mind of every rational inquirer, that the general motion which appears in the starry heavens is not real, but is caused by the rotation of the earth round its axis every day, by which we and all the inhabitants of the globe are carried round in a regular and uniform motion from west to east. When this conclusion is admitted, it removes every difficulty and every disproportion which at first appeared in the motions and arrangements of the celestial orbs, and reduces the system of the universe to a scene of beauty, harmony, and order worthy of the infinite wisdom of Him who formed the plan of the mighty fabric, and who settled "the ordinances of heaven." Instead, then, of remaining in a state of absolute rest, as we are at first apt to imagine, we are transported every moment towards the east with a motion ten times more rapid than has ever been effected by steam-carriages or air-balloons. It is true, we do not feel this motion, because it is smooth and uniform, and is never interrupted. The earth is carried forward in its course, not like a ship in the midst of a tempestuous ocean, but through a smooth ethereal sea, where all is calm and serene, and where no commotions to disturb its motion ever arise. Carried along with a velocity which is common to everything around us, we

are in a state somewhat similar to that of a person in a ship which is sailing with rapidity in a smooth current; he feels no motion except when a large wave or other body happens to dash against the vessel; he fancies himself at rest, while the shore, the buildings, and the hills appear to him to move; but the smallness of the vessel, compared with the largeness of the objects which seem to move, convinces him that the motion is connected with the ship in which he sails: and on similar principles we infer that the apparent motion of the heavens is caused by the real motion of the earth, which carries us along with it as a ship carries its passengers along the sea. With regard to motion, it may be observed that, strictly speaking, we do not *perceive* any motion either in the earth or in the heavens. When we look at a star with the utmost steadiness, we perceive no motion, although we keep our eye fixed upon it for a few minutes; but, if we mark the position of the star with regard to a tree or a chimney top, and, after an hour or two, view the star from the same station, we shall find that it then appears in a different direction. Hence we infer that motion has taken place; but whether the motion be in the star or in the persons who have been observing it, remains still to be determined. We perceive no motion in the star any more than we feel the motion of the earth. All that we perceive is, that the two objects have changed their relative positions; and, therefore, the body that is really in motion must be determined by such considerations as we have stated above.

Besides the apparent diurnal revolution of the heavens, there is another apparent motion which requires to be considered. It is well known to every one who has paid the least attention to this subject, that we do not perceive the same clusters of stars at every season of the year. If, for example, we take a view of the starry heavens on the first of October, at ten o'clock in the evening, and again, at the same hour, on the first of April, we shall find that the clusters of stars in the southern parts of the heavens are, at the latter period, altogether different from those which appeared in the former; and those which are in the neighbourhood of the pole will appear in a different position in April from what they did at the same hour in the month of October. The square of the *Great Bear*, for example, will appear immediately *below* the pole-star in October; whereas in April it

will appear as far *above* it, and near to the zenith. In the former case, the two stars called the *Pointers* will point *upward* to the pole, in the latter case they will point *downward*. In October this constellation will appear nearly in the position represented in fig. 1 (p. 24); in April it will appear nearly as represented in fig. 3 (p. 27). These variations in the appearance of the stars lead us to conclude that there is an *apparent annual motion* in these luminaries. This motion may be observed, if we take notice, for a few days or weeks, of those stars which are situated near the path of the sun. When we see a bright star near the western horizon, a little elevated above the place where the sun went down, if we continue our observation we shall find that every day it appears less elevated at the same hour, and seems to be gradually approaching to the point of the heavens in which the sun is situated, till, in the course of a week or two, it ceases to be visible, being overpowered by the superior brightness of the sun. In the course of a month or two the same star which disappeared in the west will be seen rising some time before the sun in the east, having passed from the eastern side of the sun to a distance considerably westward of him. The stars in the western quarter of the heavens which appeared more elevated will be found gradually to approximate to the sun, till they likewise disappear; and in this manner all the stars of heaven seem to have a revolution, distinct from their diurnal, from east to west, which is accomplished in the course of a year.

The different positions of the *Pleiades*, or seven stars, at different seasons of the year, will afford every observer an opportunity of perceiving this motion. About the middle of September these stars will be seen, about eight o'clock in the evening, a little to the south of the northeast point of the horizon; about the middle of January, *at the same hour*, they will be seen on the meridian, or due south; on the first of March they will be seen half way between the zenith and the western horizon; about the middle of April they will appear very near the horizon; soon after which they will be overpowered by the solar rays, and will remain invisible for nearly two months, after which they will reappear in the east, early in the morning, before the rising sun.

This annual motion of the stars evidently indicates that the sun has an *apparent* motion every day from *west* to *east*, contrary to his apparent diurnal motion, which is from east to

west. This apparent motion is at the rate of nearly *a degree* every day, a space nearly equal to twice the sun's apparent diameter. In this way the sun appears to describe a circle around the whole heavens, from west to east, in the course of a year. This apparent motion of the sun is caused by the *annual* revolution of the earth around the sun as the centre of its motion, which completely accounts for all the apparent movements in the sun and stars to which we have now adverted. If we place a candle upon a table in the midst of a room, and walk round it in a circle, and, as we proceed, mark the different parts of the opposite walls with which the candle appears coincident, when we have completed our circle the candle will appear to have made a revolution round the room. If the walls be conceived to represent the starry heavens, and the candle the sun, it will convey a rude idea of the apparent motion of the sun, and the different clusters of stars which appear at different seasons of the year in consequence of the annual motion of the earth. But this subject will be more particularly explained in the sequel.

From what we have now stated in relation to the apparent motions of the heavens, we are necessarily led to conceive of the earth as a body, placed, as it were, in the midst of infinite space, and surrounded in every direction, above, below, on the right hand and on the left, with the luminaries of heaven, which display their radiance from every quarter at immeasurable distances; and that its annual and diurnal motions account for all the movements which appear in the celestial sphere. Hence it is a necessary conclusion, that we are surrounded at all times with a host of stars, in the *daytime* as well as in the night, although they are then imperceptible. The reason why they are invisible during the day is obviously that their fainter light is overpowered by the more vivid splendour of the sun and the reflective power of the atmosphere. But although they are then imperceptible to the unassisted eye, they can be distinctly perceived, not only in the mornings and evenings, but even at noonday, while the sun is shining bright, by means of telescopes adapted to an equatorial motion; and in this way almost every star visible to the naked eye at night can be pointed out, even amid the effulgence of day, when it is within the boundary of our hemisphere. When the stars which appear in our sky at night have, in consequence of the rotation of the earth, passed from our view, in about twelve

hours afterward they will make their appearance nearly in the same manner to those who live on the opposite side of the globe; and when they have cheered the inhabitants of those places with their radiance, they will again return to adorn our nocturnal sky.

On the whole, *the starry heavens present, even to the vulgar eye, a scene of grandeur and magnificence.* We know not the particular destination of each of those luminous globes which emit their radiance to us from afar, or the specific ends it is intended to subserve in the station which it occupies, though we cannot doubt that all of them answer purposes in the Creator's plan worthy of his perfections and of their magnitude and grandeur; but we are certain that they have, at least, a remote relation to man, as well as to other beings far removed from us, in the decorations they throw around his earthly mansion. They serve as a glorious ceiling to his habitation. Like so many thousand sparkling lustres, they are hung up in the magnificent canopy which covers his abode. He perceives them shining and glittering on every hand, and the dark azure which surrounds them contributes to augment their splendour. The variety of lustre which appears in every star, from those of the sixth magnitude to those of the first, and the multifarious figures of the different constellations, present a scene as diversified as it is brilliant. What are all the decorations of a Vauxhall Garden, with its thousands of variegated lamps, compared with ten thousands of suns, diffusing their beams over our habitation from regions of space immeasurably distant? A mere gewgaw in comparison; and yet there are thousands who eagerly flock to such gaudy shows who have never spent an hour in contemplating the glories of the firmament, which may be beheld "without money and without price." That man who has never looked up with serious attention to the motions and arrangements of the heavenly orbs must be inspired with but a slender degree of reverence for the Almighty Creator, and devoid of taste for enjoying the beautiful and the sublime.

The stars not only adorn the roof of our sublunary mansion, but they are also in many respects *useful* to man. Their influences are placid and gentle. Their rays, being dispersed through spaces so vast and immense, are entirely destitute of heat by the time they arrive at our abode; so that we enjoy the view of a numerous assemblage of luminous globes with-

out any danger of their destroying the coolness of the night or the quiet of our repose. They serve to guide the traveller both by sea and land; they direct the navigator in tracing his course from one continent to another through the pathless ocean. They serve "for signs and for seasons, and for days and years." They direct the labours of the husbandman, and determine the return and conclusion of the season. They serve as a magnificent "timepiece" to determine the true length of the day and of the year, and to mark with accuracy all their subordinate divisions. They assist us in our commerce, and in endeavouring to propagate religion among the nations, by showing us our path to every region of the earth. They have enabled us to measure the circumference of the globe, to ascertain the *density* of the materials of which it is composed, and to determine the exact position of all places upon its surface. They cheer the long nights of several months in the polar regions, which would otherwise be overspread with impenetrable darkness. Above all, they open a prospect into the regions of other worlds, and tend to amplify our views of that Almighty Being who brought them into existence by his power, and "whose kingdom ruleth over all." In these arrangements of the stars in reference to our globe, the Divine wisdom and goodness may be clearly perceived. We enjoy all the advantages to which we have alluded as much as if the stars had been created solely for the use of our world, while, at the same time, they serve to diversify the nocturnal sky of other planets, and to diffuse their light and influence over ten thousands of other worlds with which they are more immediately connected; so that, in this respect, as well as in every other, the Almighty produces the most sublime and diversified effects by means the most simple and economical, and renders every part of the universe subservient to another, and to the good of the whole.

Before proceeding farther, it may be expedient to explain the *measures* by which astronomers estimate the apparent distances between any two points of the heavens. Every circle is supposed to be divided into 360 equal parts. A circle which surrounds the concavity of the heavens, as that which surrounds an artificial globe, is divided into the same number of parts. The number 360 is entirely arbitrary, and any other number, had mathematicians chosen, might have been fixed upon · and hence the French, in their measures of

the circle, divide it into 400 equal parts or degrees; each degree into 100 minutes, and each minute into 100 seconds. The reason why the number 360 appears to have been selected is, that this number may be divided into halves, quarters, and eighths, without a fraction; and, perhaps, because the year was, in former times, supposed to contain about 360 days. Each degree is divided into sixty minutes, each minute into sixty seconds, each second into sixty thirds, &c. Degrees are marked thus, °; minute, ′; seconds, ″; thirds, ‴. Thus the obliquity of the ecliptic for January 1st, 1836, was twenty-three degrees, twenty-seven minutes, forty-two seconds, which are thus expressed, 23° 27′ 42″.

It may not be improper to remark, that when we state the number of degrees between two objects, either on the earth or in the heavens, it is not intended to express the *real* distance, but only the *relative* or *apparent* distance of the objects. Thus, when we say that two places on the earth, which lie directly north and south of each other, are twenty degrees distant, it does not convey an idea of the *actual distance* of these places from each other, but only what proportion of the earth's circumference intervenes between them. If, however, we know the number of yards or miles contained in that circumference, or in a single degree of it, we can then find the actual distance, by multiplying the number of degrees by the number of miles in a degree. But this supposes that the extent of a degree on the earth's surface has been measured, and the number of yards or miles it contains ascertained. In like manner, when we say that two stars in the heavens are fifteen degrees from each other, this merely expresses their relative position, or what portion of a great circle of the celestial sphere intervenes between them, but determines nothing as to their real distance, which is far surpassing our comprehension. The real magnitude of objects or spaces in the heavens depends upon their distance. Thus, the apparent breadth or diameter of the moon is about half a degree, or nearly thirty-two minutes, and that of the sun nearly the same; but as the moon is much nearer to us than the sun, a *minute of a degree* on her surface is equal only to about seventy miles, while a minute on the sun's surface is equal to more than 28,000 miles, which is four hundred times greater. The greatest apparent diameter of Saturn is twenty seconds, or one third of a minute; the greatest diameter of Venus is fifty-eight

seconds, or nearly a minute; but as Saturn is much farther from us than Venus, his real diameter is 79,000 miles, while that of Venus is only 7,700. Before the real diameter of any object in the heavens can be determined, its distance must be first ascertained.

Those who have never been in the practice of applying angular instruments to the heavens may acquire a tolerably correct idea of the extent of space which is expressed by any number of degrees by considering that the apparent diameters of the sun and moon are about *half a degree;* that the distance between the two pointers in the Great Bear is about five degrees; that the distance between the pole-star and the nearest pointer is twenty-nine degrees; that the distance between the *Pleiades* and the ruddy star *Aldebaran*, which lies to the eastward of these stars, is fourteen degrees; that the distance between *Castor* and *Pollux* is five degrees; and the distance between *Bellatrix* and *Betelgeuse*, the stars in the right and left shoulder of *Orion*, is eight degrees. Perhaps the most definite measure for a common observer is that which is to be found in the three stars in a straight line which form the *belt* of Orion, which are known to every one, and which are distinguished in England by the name of the *Three Kings*, or the *Ell* and *Yard*, and in Scotland by "*The Lady's Elwand.*" The line which unites these three stars measures exactly three degrees, and, consequently, there is just one and a half degree between the central star and the one on each side of it. By applying this rule or yard to any of the spaces of the firmament, the number of degrees which intervenes between any two objects may be nearly ascertained. Orion is the most striking and splendid of all the constellations; and as the equator runs through the middle of it, it is visible from all the habitable parts of the globe. About the middle of January it is nearly due south at nine o'clock in the evening.

I have been somewhat particular in the above sketches of the apparent motions and phenomena of the heavens, because such descriptions are seldom or never given in elementary treatises; because I wish every lover of the science of astronomy to contemplate with his own eyes the scenery of the sky; and because such views and observations of the general aspect of the heavens are necessary in order to understand the true system of the universe.

CHAPTER II.

ON THE GENERAL ARRANGEMENT OF THE PLANETARY SYSTEM.

When we take an attentive view of the nocturnal heavens at different periods, we find that the stars never shift their positions with respect to each other. The stars, for instance, that form the constellation of Orion, preserve the same relative positions to each other every succeeding day, and month, and year. They exhibit the same general figure which they presented in the days of our fathers, and even in the times of Amos and of Job. We never see the three stars in the belt, which Job calls "the bands of Orion," move nearer to or farther from each other. We never see the pointers in the Great Bear directed on any other line than towards the pole-star, nor do we ever see *Aldebaran* to the north or south, or to the west, of the seven stars; and the same may be said, with two or three exceptions, in regard to all the stars in the heavens, which preserve invariably the same general relations to each other from one year and century to another. Hence they have been denominated *fixed stars*. But when an attentive observer surveys the heavens with minuteness, he will occasionally perceive some bodies that shift their positions. When the movements of these bodies are carefully marked, they will be found to direct their course sometimes to the east, at other times to the west, and at certain times to remain in a fixed position; but, on the whole, their motion is generally from west to east. Their motion is perceived by their appearing sometimes on one side of a star and sometimes on another. They appear to partake of the general diurnal motion of the heavens, and rise and set with the stars to which they are adjacent. These bodies have received the name of *planets*, that is, *wandering stars;* and, indeed, were their real motions such as they appear to a common observer, the name would be exceedingly appropriate. For their apparent motions are in many instances exceedingly irregular; and, were they delineated on paper, or attempted to be exhibited by machinery, they would appear an almost inextricable maze.

Ten bodies of this description have been discovered in the heavens, five of which are invisible to the naked eye, and can only be perceived by means of telescopes. They were, of course, unknown to the ancients. The names of the five which have been known in all ages are, Mercury, Venus, Mars, Jupiter, and Saturn. The names of the other five, which have been discovered within the last sixty years, are, Vesta, Juno, Ceres, Pallas, and Uranus, or Herschel.

It was long before the true magnitudes and real motions of these globes were fully ascertained. Most of the ancient astronomers supposed that the earth was a quiescent body in the centre of the universe, and that the planets revolved around it in so many different heavens, which were nearly concentric, and raised one above another in a certain order. The first or lowest sphere was the *Moon*, then *Mercury*, and, next in order, *Venus*, the *Sun*, *Mars*, *Jupiter*, *Saturn*, and then the sphere of the fixed stars. They found it no easy matter to reconcile the daily motion, which carries the stars from east to west, with another peculiar and slow motion, which carries them round the poles of the ecliptic, and from west to east, in the period of 25,000 years; and, at the same time, with a third motion, which carries them along from east to west in a year, around the poles of the ecliptic. They were no less at a loss how to reconcile the *annual* and *daily* motions of the sun, which are directly contrary to each other. An additional difficulty was found in the particular course pursued by each individual planet. It required no little ingenuity to invent celestial machinery to account for all the variety of motions which appeared among the heavenly orbs. After the first *mobiles*, or powers of motion, they placed some very large heavens of solid crystal, which, by rolling one over another, and by a mutual and violent clashing, communicated to each other the universal motion received from the *primum mobile*, or first mover; while, by a contrary motion, they resisted this general impression, and, by degrees, carried away, each after its own manner, the planet for the service of which it was designed. These heavens were conceived to be *solid;* otherwise the upper ones could have had no influence on the lower to make them perform their daily motion, and they behooved to be of the *finest crystal*, because the light of the stars could not otherwise penetrate the thickness of these arches applied one over another, nor reach our eyes Above the sphere of the

fixed stars were placed the first and second crystalline heavens, and above these the *primum mobile*, which carried round all the subordinate spheres. They imagined that the *primum mobile* was circumscribed by the empyreal heaven, of a cubic form, which they supposed to be the blessed abode of departed souls. Some astronomers were contented with seven or eight different spheres, while others imagined no less than seventy of them wrapped up one within another, and all in separate motions. They no sooner discovered some new motion or effect, formerly unknown, than they immediately set to work and patched up a new sphere, giving it such motions and directions as were deemed requisite. Cycles, epicycles, deferents, centric and eccentric circles, solid spheres, and other celestial machinery, were all employed to solve the intricate motions of the heavens, which seemed to baffle all the efforts of human ingenuity. After their system was supposed to be completed, new anomalies were detected, which required new pieces of machinery to be applied to solve appearances. But after all the ingenuity displayed in their patchings and repatchings, the celestial spheres could never be got to move onward in harmony, and in accordance with the phenomena of the heavens.*

It would be no easy task to describe how their epicycles could be made to move through the thick crusts of crystal of which their spheres were made. They, however, found some means or other to extricate themselves from every difficulty, as they always had recourse to geometrical lines, which never found any obstacle to their passage on paper. To make all the pieces of their machinery move with as much smoothness and as little inconsistency as possible, they were forced to delineate certain furrows, or to notch on the arches certain grooves, in which they jointed and made the tenons and mortises of their epicycles to slide. All this celestial joiner's work, to which succeeding astronomers added several pieces to produce balancings, or perpetual goings backward and forward, had no other tendency than to conceal the sublime and beautiful simplicity of nature, and to prevent mankind, for many ages, from recognising the true system of the world. With all their cumbrous and complicated machinery, they never could account for the motions and other phenomena of

* See La Pluche's "*Spectacle de la Nature.*"

Mercury and Venus, and the different apparent magnitudes which the planets present in different parts of their orbits. Without admitting the motion of the earth, it would surpass the wisdom of an angel, on any rational principles, to solve the phenomena of the heavens. This is the system which has been denominated the *Ptolemaic*, from Ptolemy, an astronomer in Egypt, who first gave a particular explanation of its details; but it is understood to have been received by the ancient Greek philosophers, except the Pythagoreans. It was supported by Aristotle, who wrote against the motion of the earth; and as the authority of this philosopher was thought sufficient to establish the opinion of the earth being a quiescent body, it was generally received by the learned in Europe till the sixteenth century, or a little after the period of the Reformation. This is the system to which almost all our theological writers, even of the seventeenth century, uniformly refer, when alluding to the heavenly bodies and to the general frame of the world; and, in consequence of admitting so absurd and untenable a theory, their reflections and remarks in reference to the objects of the visible world, and many of their comments on scripture, are frequently injudicious and puerile, and, in many instances, worse than useless. That such a clumsy and bungling system was so long in vogue, is a disgrace to the ages in which it prevailed, and shows that even the learned were more prone to frame hypotheses and to submit to the authority of Aristotle, than to follow the path of observation, and to contemplate with their own eyes the phenomena of the universe. To suppose that the Architect of nature was the author of such a complex and clumsy piece of machinery was little short of a libel on his perfections, and a virtual denial of his infinite wisdom and intelligence.

> "Oh how unlike the complex works of man,
> Heaven's easy, artless, unencumber'd plan."

From this brief sketch of the Ptolemaic system, we may learn into how many absurdities we involve ourselves by the denial of a single important fact and the admission of a single false principle; and the importance of substantiating every fact and proving every principle in all our investigations of the system of nature and the order of the universe.

The first among the moderns who had the boldness to assail

the ancient system which had so long prevailed was the famous *Nicolaus Copernicus*, who was born at Thorn, in Polish Prussia, in 1472, and died at Worms, where he had been made a canon of the church by his mother's brother, who was bishop of that place. His attention was early directed to the sciences of mathematics and astronomy. Having travelled into Italy for the purpose of enlarging his knowledge on such subjects, he remained some time at Bologna with Dominicus Maria, an eminent professor of astronomy, and afterward went to Rome, where he soon acquired so great a reputation that he was chosen professor of mathematics, which he taught for a long time with great applause. At the same time he was unwearied in making celestial observations. Returning to his own country, he began to apply his vast knowledge in mathematics to correct the system of astronomy which then prevailed. Having applied himself with assiduity to the study of the heavens, he soon perceived that the hypothesis of the ancient astronomers was conformable neither to harmony, uniformity, nor reason. With a bold independent spirit, and a daring hand, he dashed the crystalline spheres of Ptolemy to pieces, swept away his cycles, epicyles, and deferents, stopped the rapid whirl of the primum mobile, fixed the sun in the centre of the planetary orbs, removed the earth from its quiescent state, and set it in motion through the ethereal void along with the other planets, and thus introduced simplicity and harmony into the system of the universe. But such a bold attack on ancient systems, which had been so long venerated, could not be made without danger. Even the learned set themselves in opposition to such bold innovations in philosophy; the vulgar considered such doctrines as chimeras, contrary to the evidence of their senses, and allied to the ravings of a maniac; and the church thundered its anathemas against all such opinions as most dangerous heresies. When only about thirty-five years of age, Copernicus wrote his book "On the Revolution of the Celestial Orbs;" but, fearing the obloquy and persecution to which his opinions might expose him, he withheld its publication, and communicated his views only to a few friends. For more than thirty years he postponed the publishing of this celebrated work, in which his system is demonstrated; and it was with the utmost difficulty, even in the latter part of his life, that he could be prevailed upon to usher it into the world. Overcome, at length,

by the importunity of his friends, he put the work in order, and dedicated it to Pope Paul III.; in which dedication, not to shock received prejudices, he presented his system under the form of a hypothesis. "Astronomers," said he, "being permitted to imagine circles to explain the motion of the stars, I thought myself equally entitled to examine if the supposition of the motion of the earth would render the theory of these appearances more exact and simple." The work was printed at Nuremberg at the expense of his friends, who wrote a preface to it, in order to palliate, as much as possible, so extraordinary an innovation. But its immortal author did not live to behold the success of his work. He was attacked by a bloody flux, which was succeeded by a palsy in his left side; and only a few hours before he breathed his last he received a copy of his work, which had been sent him by one of his scientific friends. But he had then other cares upon his mind, and composedly resigned his soul to God on the 23d of May, 1543, in the seventy-first year of his age. His remains were deposited in the cathedral of Frauenberg; and spheres cut out in relief on his tomb were the only epitaph that recorded his labours. Not many years ago his bones were wantonly carried off to gratify the impious curiosity of two Polish travellers.*

The system broached by Copernicus, notwithstanding much opposition, soon made its way among the learned in Europe. It was afterward powerfully supported by the observations and reasonings of Galileo, Kepler, Halley, Newton, La Place, and other celebrated philosophers, and now rests on a foundation firm and immutable as the laws of the universe. The introduction of this system may be considered an era as important in philosophy as that of the Reformation was in politics and religion. It had even a bearing upon the progress of religion itself, and upon the views we ought to take of the character and operations of the great Creator. It paved the way for a rational contemplation of his works, and for all those brilliant discoveries in the celestial regions which have expanded our views of his adorable perfections, and of the boundless extent of his universal empire It was promulgated nearly at

* A *fac-simile* of one of the letters of Copernicus may be seen in No. IX. of the "Edinburgh Philosophical Journal" for July, 1821; and an engraving of the house in which he lived in No. XIII. of the same Journal for July, 1822.

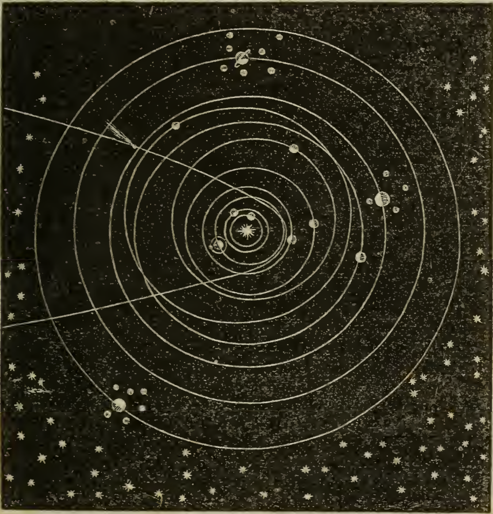
the same period when the superstitions of the dark ages were beginning to be dissipated; when the power of the Romish church had lost its ascendency; when the art of printing had begun to illuminate the world; when the mariner's compass was applied to the art of navigation; when the western continent was discovered by Columbus; and when knowledge was beginning to diffuse its benign influence over the nations; and, therefore, it may be considered as connected with that series of events which are destined, in the moral government of God, to enlighten and renovate the world.

I shall now proceed to consider the arrangement of the planetary or Copernican system, and some of the arguments by which it is supported.

In this system the sun is considered as placed near the centre. Around this central luminary the planets perform their revolutions in the following order:—First, the plane. Mercury, at the distance from the sun's centre of about 37 millions of miles. Next to Mercury is Venus, distinguished by the name of the morning and evening star, at the distance of 31 millions of miles from the orbit of Mercury, and 68 millions from the sun. The Earth is considered as the planet next in order, which revolves at the distance of 95 millions of miles from the sun, and 27 millions from the orbit of Venus. Farther from the sun than the Earth is the planet Mars, which is 145 millions of miles from the sun, and 50 millions beyond the orbit of the Earth. Next to the orbit of Mars are four small planetary bodies, sometimes named *Asteroids*, which were discovered at different times about the beginning of the present century. They are named Vesta, Juno, Ceres, and Pallas. Of these, the first in order from the sun is Vesta, at the distance of 225 millions of miles; the next, Juno, at the distance of 253 millions Ceres, at 260 millions; and Pallas, at 266 millions of miles. The planet Jupiter is the next in order, and performs its revolution in an orbit 495 millions of miles from the sun, and 400 from the orbit of the earth. Saturn is nearly double the distance of Jupiter from the sun, being distant from that orb above 900 millions of miles. The most distant planet in the system which has yet been discovered is Uranus, or Herschel, which is removed from the sun at more than double the distance of Saturn; namely, above 1800 millions of miles. The orbit of this planet includes the orbits of the whole of the bodies of the

solar system that have hitherto been discovered, and is eleven thousand three hundred millions of miles in circumference, and three thousand six hundred millions in diameter. To move round this circumference at the rate of thirty miles every hour would require above forty-two thousand nine hundred years. Such is the order, and such are the ample dimensions of that system of which we form a part; and yet it is but a mere speck in the map of the universe. The following diagram exhibits the order of the planets in the solar system:

FIG. V.



In the above figure the small central star represents the sun, and the circles represent the orbits of Mercury, Venus, the Earth, Mars, Vesta, Juno, Ceres, Pallas, Jupiter, Saturn,

and Uranus, in the order here enumerated. The orbits of the new planets, Vesta, Juno, Ceres, and Pallas, are represented as crossing each other, as they do in nature; and the portion of a long ellipse which crosses the orbits of all the planets represents the orbit of a comet. The *proportional distances* and *magnitudes* of the planets are represented in a subsequent chapter.

I shall now proceed to offer a few arguments or demonstrations of the truth of the solar system, as first proposed by Copernicus, and now received by all astronomers. I shall first state those which may be called presumptive arguments, or which amount to a high degree of probability, and then briefly illustrate those which I consider as demonstrative. Having already endeavoured to prove the diurnal rotation of the earth, I shall consider that point as settled, and confine myself, at present, to the consideration of the earth's *annual revolution*, and the phenomena of the planets which result from this motion.

The presumptive arguments that the earth is a planetary body, and revolves round the sun in concert with other planets, are, 1. *It is most simple and agreeable to the general arrangements of the Creator* that such an order as we have now stated should exist in the planetary system. For, by the motion of the earth, all the phenomena of the heavens are resolved and completely accounted for, which they cannot be on any other system, without the supposition of clumsy and complex machinery and motions altogether repugnant to reason and to what we know of the other operations of the all-wise Creator. Besides, it is contrary to the first rule laid down in philosophy—"That more causes of natural things are not to be admitted than are both true and sufficient to explain the phenomena." But the Ptolemaic, or vulgar system of the world, assumes the existence of facts which can never be established, and introduces cumbrous and complicated motions which are quite unnecessary for explaining the phenomena. 2. Because *it is more rational to suppose that the earth moves about the sun, than that the huge masses of the planets*, some of which are a thousand times larger than our globe—or that the stupendous body of the sun, which is thirteen hundred thousand times greater—*should perform a revolution around so comparatively small a globe as the earth.* To suppose the contrary would be repugnant to all the laws of motion that

are known to exist in the universe. We might as well expect that a sling, which contains a millstone in it, may be fastened to a pebble, and continue its motion about that pebble without removing it, as that the sun can revolve about the earth while the earth continues immoveable in the centre of that motion.

3. It was a law discovered by Kepler, by which all the planets, both primary and secondary, are regulated, "That the squares of the periodic times of the planets' revolutions are as the cubes of their distances;"* but, if the sun move around the earth, that law, which is established on the most accurate observations, is completely destroyed, and the general order and symmetry of the system of nature are infringed upon and interrupted. For, according to that law, the sun would be so far from revolving about the earth in 365 days, that it would require no less than 589 years to accomplish one revolution, as will appear from the following calculation: The moon revolves round the earth in twenty-seven days eight hours, at the distance of 240,000 miles; the sun is placed at the distance of 95,000,000 miles. The period of the revolution of any body revolving at that distance will be found, according to the law now stated, by the following proportion: As the cube of the moon's distance : is to the cube of the sun's distance : : so is the square of the moon's period : to the square of the period of any body moving about the earth at the distance of the sun. Now, the cube of the moon's distance, 240,000, is 13,824,000,000,000,000; the cube of the sun's distance, 95,000,000, is 857,375,000,000,000,000,000,000. The square of the moon's periodical time, twenty-seven days eight hours, is 747, which, multiplied by the cube of the sun's distance, and divided by the cube of the moon's distance, is 46,329,508,463, the square root of which is 215,242 days, or 589 years and 257 days. This calculation is of itself sufficient to determine the point in question, for there is no exception known to the law we have stated. Besides, did the sun observe this universal law, and yet revolve in 365 days, his distance ought to be only about 1,351,000 miles, whereas it

* For example; if one planet were four times as distant as another, it would revolve in a period eight times as long; for the cube of 4=64 is equal to the square of 8. Thus Mars is about four times as remote from the sun as Mercury, and Uranus four times as remote as Jupiter, and their periods of revolution correspond to this proportion of their distances. This argument, when properly understood, is demonstrative

can be shown that it is about 95,000,000. For, as the square of the moon's period, 747 : is to the square of the sun's, 365 × 365=133,225 : : so is the cube of the moon's distance from the earth 13,824,000,000,000,000 : to 2,465,465,050,240,963,855, the cube root of which is 1,351,295, or one million, three hundred and fifty-one thousand, two hundred and ninety-five miles, which should be the sun's distance if he revolved about the earth in accordance with this universal law, which governs every moving body, both primary and secondary.*

4. It appears most reasonable to conclude that the sun is placed near the centre of the planetary system, as it is the fountain of light and heat for cheering and irradiating all the worlds within the sphere of its influence; and it is from the centre alone that these emanations can be distributed in uniform and equable proportions to all the planets. If the earth were in the centre, with the sun and planets revolving around it, the planetary worlds would be, at different times, at very different distances from the sun; and, when nearest to him, would be scorched with excessive heat, and at their greatest distance would be frozen with excessive cold; and as some of the planets would, on this supposition, be sometimes five times the distance from the source of light and heat which they are at other times, it would produce the same effect as if the earth were occasionally to be carried beyond the orbit of Jupiter, four hundred and seventy millions of miles from its present position. But if the sun be considered as placed in the centre of the system, we have then presented to our view a system of universal harmony and order: the planets all revolving around the great central orb by the universal law or power of gravitation, and everything corresponding to the laws of circular motion and central forces; otherwise we are left entirely in the dark as to the operations of nature and the system of the universe.

There is no more difficulty in conceiving the earth to move than that it should remain quiescent in the same place. For if the earth remain at rest in the centre of the system, it is supported upon nothing, in the midst of infinite space, by the power of Omnipotence: and we have as little conception how

* The *primary* planets are those which revolve about the sun as their centre, as Venus, Mars, and Jupiter. The *secondary* planets are those which revolve around the primary, as the moons of Jupiter, Saturn, and Uranus

a ponderous globe of the size of the earth should remain suspended upon *nothing*, as that it should move through the voids of space with a velocity of sixty-eight thousand miles an hour. The Power that is able to suspend it in empty space can as easily make it fly through the ethereal regions, as is the case with Jupiter and Saturn, which are globes a thousand times larger; and such a motion is *necessary* in order to display the harmony and proportion of the Creator's works, and to vindicate his all-perfect wisdom and intelligence. It is even no more difficult to conceive such a motion than it is to conceive how the earth can be inhabited all around, and that there can be no such thing as *up* or *down* in the universe, absolutely considered; how, for example, persons can stand upright on the opposite sides of the globe; that our antipodes, standing with their heads in an opposite direction to ours, can look *up* to the sky and *down* to the earth just as we do, without any more danger of falling off from its surface than we are in of being carried upward into the air. These are circumstances which necessarily flow from the rotundity of the earth and its attractive power; they are known to every one, and cannot possibly be disputed, unless we deny the globular form of the earth, or, in other words, contradict the evidence both of our reason and our senses. But we know as little of that power which draws everything to the earth on all sides, as we do of a power which carries a planet round its orbit at the rate of a hundred thousand miles an hour. Both are effects of that Almighty agent who contrived the universe, "who is wonderful in counsel and excellent in working," and "whose ways," in numerous instances, "are past finding out." But, in all cases where the least doubt exists, we ought to adopt that view of the Creator's plans and operations which is most consistent with the ideas of a Being of infinite perfection.

The arguments now stated, although we could produce no other, would be sufficient to corroborate the idea that the earth is a planetary body, performing its motion through the depths of space; but, happily, we are able to produce proofs of the sun occupying the centre of the system, which may be considered as demonstrative. Those proofs I shall now state as briefly as possible.

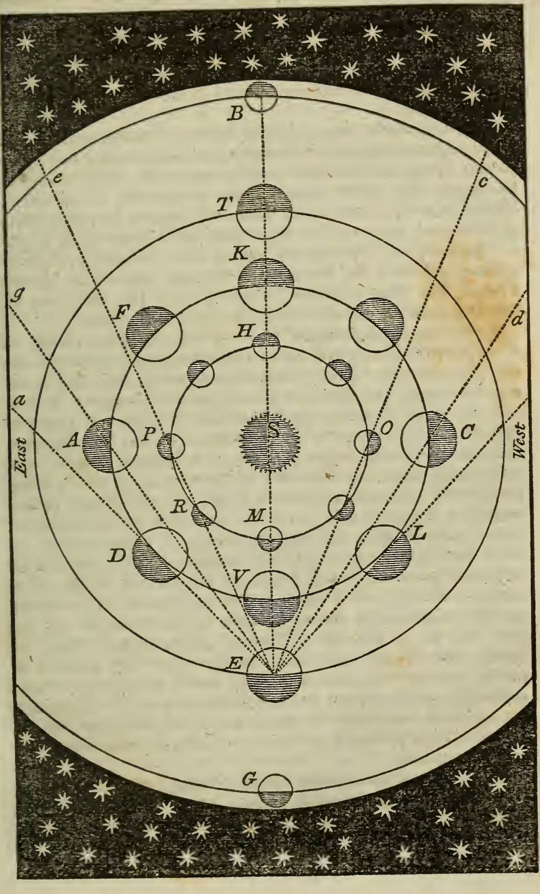
1. In the first place, the planets Mercury and Venus are uniformly observed to have two conjunctions with the sun,

but no opposition, which could not possibly happen unless the orbits of those planets lay *within* the orbit of the earth, as delineated in the plan of the solar system. This circumstance will be more particularly understood by the diagram opposite.

Let S represent the sun in the centre of the system; M, Mercury; V, Venus; E, Earth; and G, Mars. It is evident, that when Mercury is at M and Venus at V, they will be seen from the earth, E, in the same part of the heavens as the sun; namely, at B, where Mars is represented; because they are all situated in the same straight line, $E\ B$. In this position they are between the sun and the earth, and this is called their *inferior* conjunction. Again, when Mercury and Venus come to the situations H, K, they are again in the straight line joining the centres of the earth and sun, and are therefore seen in the same part of the heavens with that orb. In these last positions they are *beyond* the sun, which is now between them and the earth. This is called their *superior* conjunction. Here it is evident that these two planets must appear twice in conjunction with the sun, in each revolution, to a spectator on the earth at E; but they can never appear *in opposition* to the sun, or, in other words, they can never be seen in the east immediately after the sun has set in the west, as is the case with Mars, which may be seen at G when the sun appears at B, in the opposite direction; all which appearances are exactly correspondent with observation, but could never take place if the earth were the centre of their motions.

2. The greatest *elongation* or distance of Mercury from the sun is twenty-nine degrees, and that of Venus about forty-seven degrees, which answers exactly to observation, and to the positions and distances assigned to them in the system; but if they moved round the earth as a centre, they would sometimes be seen 180 degrees from the sun, or *in opposition* to him. But they have never been seen in such a position by any observer, either in ancient or modern times, nor at greater distances from the sun than those now specified. It is evident, from the figure, that when Venus is at D, the point of its greatest elongation, it will be seen at a, in the direction of $E\ a$, which forms an angle of forty-seven degrees with the line $E\ B$, or the direction of the sun as seen from the earth. In like manner Mercury, when at its greatest elongation, at R,

FIG. VI.



will be seen at *e*, which forms a less angle than the former with the line of direction in which the sun is seen. Hence it is that Mercury is so rarely seen, and Venus only at certain times of the year; whereas, were the earth at rest in the centre of the planetary orbits, these planets would be seen in all positions and distances from the sun in the same manner as the moon appears.

3. The planets Mars, Jupiter, Saturn, Uranus, and all the other superior planets, have each their *conjunctions* and *oppositions* to the sun, alternate and successively, which could not be unless their orbits were *exterior* to the orbit of the earth. Thus, from the earth at *E* Mars will appear in conjunction with the sun at *B* and in opposition at *G*; that is, in a part of the heavens 180 degrees distant from the sun, or directly opposite to him; and the same is the case with all the planets beyond the orbit of Mars, which proves that they are all situated in orbits which *include* the orbit of the earth.

4. In the arrangements of the planets in the system, as formerly stated, they will all be sometimes much nearer to the earth than at other times; and, consequently, their brightness and splendour, and likewise their *apparent diameters*, will be proportionably greater at one time than at another. This corresponds with every day's observation. Thus the apparent diameter of Venus, when greatest, is fifty-eight seconds, and when least, about ten seconds; of Mars, when greatest, about twenty-five seconds, and when least, not above four or five seconds; so that in one part of his orbit he is five times nearer to the earth than at the opposite part, and, consequently, appears twenty-five times larger in surface. Thus, when Mars is in the point *G*, in opposition to the sun, he is the whole diameter of the earth's orbit, or 190 millions of miles nearer us than when he is in conjunction, in the point *B*. In the one case he is only 50 millions of miles distant from the earth, while in the other he is no less than 240 millions of miles; and his apparent magnitude varies accordingly. But, according to the system which places the earth in the centre, the apparent magnitude of Mars, and of all the other planets, should always be equal, in whatever points of their orbits they may be situated.

5. When the planets are viewed through good telescopes, they appear with different phases; that is, with different parts of their bodies enlightened. Thus, Mars sometimes

appears round, or with a full enlightened face; and at other times he presents a gibbous phase, like that of the moon three or four days before the full. Venus presents all the different phases of the moon, appearing sometimes with a gibbous phase, sometimes like a half moon, and at other times like a slender crescent. Thus, at *V*, her dark side is turned to the earth, and she is consequently invisible, unless she happens to pass across the disk of the sun, when she appears like a round black spot on the surface of that luminary. At *D* she appears like a crescent; at *A* like a half moon, because only the one half of her enlightened side is turned towards the earth; and at *F* she presents a gibbous phase. When Copernicus first proposed his system, it was one of the strongest objections which his adversaries brought against it, and by which they supposed they had completely confuted him; namely, that "if his hypothesis were true, Venus and Mercury must vary their phases like the moon, but that they constantly appeared round." Copernicus at once admitted that these consequences were justly drawn; and he attributed the cause of their round appearances to the structure of our eyes, to the distance of the objects, and to those radiating crowns which hinder us from judging either of the size or the exact form of the stars and planets; and he is said to have prophesied that one day or other these various phases would be discovered; and little more than half a century intervened, when the telescope (which was unknown in the time of Copernicus), in the hands of Galileo, determined to a certainty the matter in dispute, and confirmed the prediction of that eminent astronomer. How great, may we suppose, would have been the transport of that illustrious man had a telescope been put into his hands, and had he seen, as we now do, that Venus, when she appears most brilliant, exhibits, in reality, the form of a crescent! so that this formidable objection to the truth of his system has now become one of the strongest and most palpable demonstrations of the reality of that arrangement which has placed the sun in the centre, and set the earth in motion between Mars and Venus.

6. All the planets in their motions are seen sometimes to move *direct;* sometimes *retrograde;* and at other times to remain *stationary*, without any apparent motion: in other words, in one part of their course they appear to move to the *east;* in another part to the *west;* and at certain points of their orbit they appear fixed for some time in the same posi-

tion. Thus, Venus, when she passes from her greatest elongation westward, at L, to her elongation eastward, at D, through the arch $L\ C\ K\ F\ A\ D$, will appear *direct* in motion, or from west to east; but as she passes from D to L, through the arch $D\ V\ L$, she will appear *retrograde*, or as if she were moving from east to west. When she is in those parts of her orbit most distant from the sun, as at D and L, she will appear for some time stationary, because the tangent line or visual ray appears to coincide for some time with the orbit of the planet; just as a ship at a great distance, when moving directly towards the eye in the line of vision, appears for a little time to make no progress. All these apparent diversities of motion are *necessary* results of the Copernican system, and they coincide with the most accurate observations; but they are altogether inexplicable on any other hypothesis.

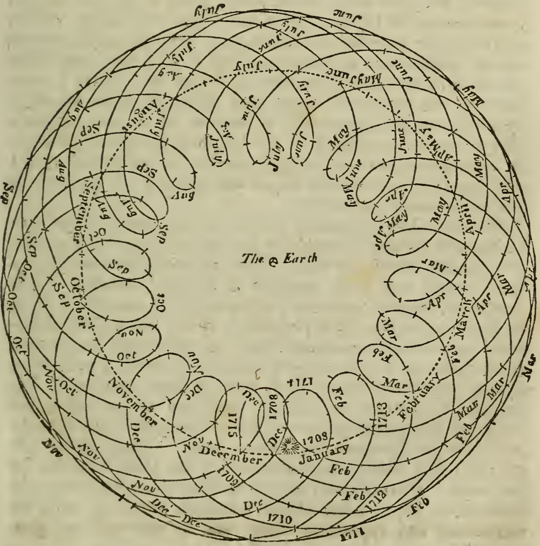
7. The planets Mercury and Venus, in their superior conjunctions with the sun, as at H and K, are sometimes hid behind the sun's body; which could never happen on the Ptolemaic hypothesis, because in it the orbit of the sun is supposed to be *exterior* to the orbits of these two planets.

8. The *times* in which these conjunctions, oppositions, direct and retrograde motions, and stationary aspects of the planets happen, are not such as they would be if the earth were at rest in its orbit; but *precisely* such if the earth move, and all the other planets in the periods assigned them. Thus, suppose Venus at any time in conjunction with the sun at V; were the earth at rest in E, the next conjunction of the same kind would happen again when Venus had made just one revolution, that is, in 224 days. But this is contrary to experience; for a much longer time is found to intervene between two conjunctions of the same kind, as must be if we suppose the earth to have a motion in the same direction. For, when Venus comes to the point V, the earth will have passed in that time from E to some other part of its orbit, and from this part still keeps moving on till Venus overtakes it, and gets again between it and the sun. The period which Venus will take before she overtakes the earth and comes in conjunction with the sun, is found as follows: The daily mean motion of the earth is fifty-nine minutes eight seconds (which is the same as the *apparent* mean motion of the sun), and the daily mean motion of Venus is one degree, thirty-six minutes, eight seconds. The difference of these mean motions is thirty-seven minutes. Therefore, as 37′ is to the number

minutes in the whole circle of 360 degrees, namely, 21600′ : so is one day : to 583 days, 18 5-4 hours, which is the time between two conjunctions of the same kind, or one year and a little more than seven months, which is somewhat more than two and a half revolutions of Venus, and which perfectly agrees with the most accurate observations.

In the last place, if we were to suppose the earth at rest in the centre of the planetary system, *the motions of all the planets would present a scene of inextricable confusion.* They would appear so irregular and anomalous that no rational being would ever suppose they could be the contrivances of an all-wise Being, possessed of every perfection. This will appear at once by casting the eye on Fig. VII., which represents the

FIG. VII.



apparent motion of the planet Mercury, as seen from the earth, from the year 1708 to 1715, as originally delineated by the celebrated astronomer Cassini, and published in the Memoirs of the Royal Academy of Sciences. Here the motion of this planet appears to describe a complicated curve, or a series of loops or spirals running into each other, instead of a regular circular motion in an orbit; and such irregular curves must be the *real* motion of the planet, to account for all its appearances, if the earth were considered as remaining fixed in the centre of its motion. On each side of the loops in the figure it appears stationary; in that part of the loop next the earth it appears retrograde; and in all the rest of the path, which seems to stretch far away from the earth, it appears direct, till its course again appears to run into a loop. Let the reader trace the whole of the curve here delineated, and then ask himself whether such motions can possibly be real, or the contrivances of Infinite Wisdom. The motions of Venus, and of all the superior planets, as seen from the earth, present similar curves and anomalies. Now it is a fact, that when the earth is considered as moving round the sun in a year, between the orbits of Venus and Mars, all these apparent irregularities are completely accounted for by the combination of motions produced by our continual change of position, in consequence of the earth's progress in its annual orbit; and thus the movements of all the planets are reduced to perfect harmony and order.

Such is a brief summary of the leading proofs which may be brought forward to establish the fact of the annual motion of the earth round the sun. They all converge towards the same point, and hang together in perfect harmony. It is next to impossible that such a combination of arguments could be found to prove a false position. When thoroughly understood and calmly considered, they are calculated to produce on the mind of every unbiased inquirer as strong a conviction of the point in question, as if, from a fixed position in the heavens, we actually beheld the earth and all its population sweeping along through the ethereal spaces with the velocity of sixty-eight thousand miles every hour. These arguments are plain and easy to be understood if the least attention be bestowed. Most of them require nothing more than common observation, or, in other words, common sense, in order to understand and appreciate them; and he who will not give

himself the trouble to weigh them with attention must be contented to remain in ignorance. I have stated them with more particularity than is generally done in elementary books on this subject, because they lie at the foundation of astronomical science, and of all our views of the amplitude and order of the universe ; and because many profess to believe in the motion of the earth merely on the authority of others, without examining the grounds of their belief, and, consequently, are never fully and rationally convinced of the important position to which we have adverted.

The motion of the earth presents before us *a most sublime and august object of contemplation.* We wonder at beholding a steam carriage, with all its apparatus of wagons and passengers, carried forward on a railway at the rate of thirty miles an hour, or a balloon sweeping through the atmosphere with a velocity of sixty miles in the same time. Our admiration would be raised still higher, should we behold Mount Etna, with its seventy cities, towns, and villages, and its hundred thousand inhabitants, detached from its foundations, carried aloft through the air, pouring forth torrents of red-hot lava, and impelled to the continent of America in the space of half an hour. But such an object, grand and astonishing as it would be, could convey no adequate idea of the grandeur of such a body as the earth flying through the voids of space in its course round the sun. Mount Etna, indeed, contains a mass of matter equal to more than 800 cubical miles, but the earth comprises an extent of more than 263,000,000,000 of solid miles, and, consequently, is more than three hundred millions of times larger than Etna, and of a much greater density. The comparative size of this mountain to the earth may be apprehended by conceiving three hundred millions of guineas laid in a straight line, which would extend 4700 miles, or from London to the equator or to South America. The whole line of guineas throughout this vast extent would represent the bulk of the earth, and a single guinea, which is only about an inch in extent, would represent the size of Etna compared with that of the earth. Again: Etna, in moving from its present situation to America in half an hour, would move only at the rate of 130 miles in a minute ; while the earth in its annual course flies with a velocity of more than 1130 miles in the same space of time, or about nine times that velocity.

How august, then, and overpowering the idea, that during

every pulse that beats within us we are carried nearly twenty miles from that portion of absolute space we occupied before! that during the seven hours we repose in sleep, we, and all the inhabitants of the world, are transported 470,000 miles through the depths of space; that during the time it would take to read deliberately from the beginning of the last paragraph to the present sentence we have been carried forward with the earth's motion more than 4500 miles; and that, in the course of the few minutes we spend in walking a mile, we are conveyed through a portion of absolute space to the extent of more than 18,000 miles. What an astonishing idea does such a motion convey of the ENERGIES of the Almighty Creator, especially when we consider that thousands of rolling worlds, some of them immensely larger than our globe, are impelled with similar velocities, and have, for many centuries past, been running without intermission their destined rounds! Here, then, we have a magnificent scene presented to view, far more wonderful than all the enchanted palaces rising and vanishing at the stroke of the magician's rod, or all the scenes which the human imagination has ever created, or the tales of romance have recorded, which may serve to occupy our mental contemplation when we feel *ennui*, or are at a loss for subjects of amusement or reflection. We may view in imagination this ponderous globe on which we reside, with all its load of continents, islands, oceans, and its millions of population, wheeling its course through the heavens at a rate of motion, *every day*, exceeding 1,600,000 miles; we may transport ourselves to distant regions, and contemplate globes far more magnificent, moving with similar or even greater velocities; we may wing our flight to the starry firmament, where worlds unnumbered run their ample rounds, where suns revolve around suns, and systems around systems, around the throne of the Eternal; till, overpowered with the immensity of space and motion, we fall down with reverence, and worship HIM who presides over all the departments of universal nature, "who created all worlds, and for whose pleasure they are and were created."

CHAPTER III.

ON THE MAGNITUDES, MOTIONS, AND OTHER PHENOMENA OF THE BODIES CONNECTED WITH THE SOLAR SYSTEM.

In the elucidation of this subject I shall, in the first place, present a few sketches of the magnitudes, motions, and other phenomena of the primary planets belonging to the solar system. These planets, as formerly stated, are, Mercury, Venus, Mars, Vesta, Juno, Ceres, Pallas, Jupiter, Saturn, and Uranus, which are here mentioned in the order of their distance from the sun.

In this order I shall proceed to give a few descriptions of the principal facts which have been ascertained respecting each planet.

I. THE PLANET MERCURY.

This planet is the nearest to the sun of any that have yet been discovered, although a space of no less than thirty seven millions of miles intervenes between Mercury and the central luminary. Within this immense space several planets may revolve, though they may never be detected by us, on account of their proximity to the sun. To an inhabitant of Mercury, such planets, if any exist, may be as distinctly visible as Venus and Mercury are to us; because they will appear, in certain parts of their course, at a much greater elongation from the sun than they can to us. This planet, on account of its moving in the neighbourhood of the sun, is seldom noticed by a common observer. It is only to be seen by the naked eye about the period of its greatest elongation from the sun, which is sometimes only about 16° or 17°, and never exceeds 29°. These elongations happen, at an average, about six or seven times every year; about three times when the planet is eastward of the sun, and three times when it is to the westward. This planet, therefore, can only be seen by the unassisted eye for a few days about these periods, either in the morning a little before sunrise, or in the evenings a little after sunset.

As it is sometimes not above 16°, even at its greatest elongation, from the point of sunrise or sunset, and is likewise very near the horizon, it is sometimes very difficult to distinguish it by the naked eye, and at all other times it is generally imperceptible without a telescope. It is said that the celebrated astronomer Copernicus had never an opportunity of seeing this planet during the whole course of his life. I have seen Mercury three or four times with the naked eye, and pretty frequently with a telescope. With a magnifying power of 150 times I have seen it about the time of its greatest elongation, more than half an hour after sunrise, when it appeared like a small brilliant half moon; but no spots could be discovered upon it. To the naked eye, when it is placed in a favourable position, it appears with a brilliant white light, like that of Venus, but much smaller and less conspicuous. The best mode of detecting it is by means of an equatorial telescope, which, by a slight calculation and the help of an ephemeris, may be directed to the precise point of the heavens where it is situated. The most favourable seasons of the year for observing it are when its greatest elongations happen in the month of March or April, and in August or September In winter it is not easily perceived, on account of its very low altitude above the horizon at sunrise and sunset; and in summer, the long twilight prevents our perception of any small object in the heavens. From the planets Saturn and Uranus, Mercury would be altogether invisible, being completely immersed in the splendour of the solar rays; so that an inhabitant of these planets would never know that such a body existed in the universe, unless he should happen to see it when it passed, like a small dark point, across the disk of the sun.

Mercury revolves around the sun in the space of eighty-seven days twenty-three hours, which is the length of its year; but the time from one conjunction to the same conjunction again is about 116 days; for as the earth has moved about a fourth part of its revolution during this period, it requires nearly thirty days for Mercury to overtake it, so as to be in a line with the sun. During this period of about 116 days it passes through all the phases of the moon, sometimes presenting a gibbous phase, sometimes that of a half moon, and at other times the form of a crescent; which phases and other particulars will be more particularly explained in the descrip-

tion I shall give of the planet Venus. Mercury, at different times, makes a transit across the sun's disk; and as its dark side is then turned to the earth, it will appear like a round spot upon the face of the sun; and when it passes near the centre of the sun it will appear for the space of from five to seven hours on the surface of that orb. Its last transit happened on the 7th of November, 1835, which was visible in the United States of America, but not in Britain, as the sun was set before its commencement. The next transits, to the end of the present century, are as follow:—

	hours.	minutes.	
1845, May 8th	7	54	P.M.
1848, November 9th ...	1	38	P.M.
1861, November 12th .	7	20	P.M.
1868, November 5th ...	6	44	A.M.
1878, May 6th	6	38	P.M.
1881, November 8th ...	0	40	A.M.
1891, May 10th	2	45	A.M.
1894, November 10th .	6	17	P.M.

The time stated in the above table is the mean time of conjunction at Greenwich, or nearly the middle of the transit; so that, in whatever part of the world the sun is risen at that time, the transit will be visible if no clouds interpose. The next two transits, in 1845 and 1848, will be partly visible in Britain.

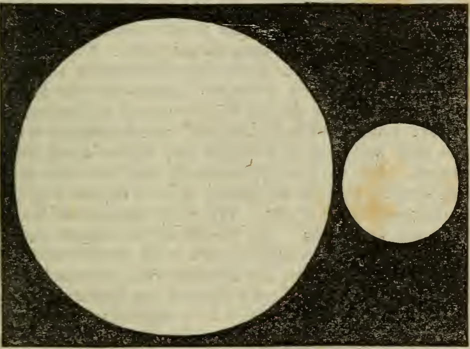
Few discoveries have been made on the surface of this planet by means of the telescope, owing to the dazzling splendour of its rays, which prevents the telescope from presenting a well-defined image of its disk; owing, likewise, to the short interval during which observations can be made, and particularly to its proximity to the horizon, and the undulating vapours through which it is then viewed. That unwearied observer of the heavens, Sir William Herschel, although he frequently viewed this planet with magnifying powers of 200 and 300 times, could perceive no spots or any other phenomenon on its disk from which any conclusions could be deduced respecting its peculiar constitution or the period of its rotation. Mr. Schroeter, an eminent German astronomer, however, appears to have been more successful. This gentleman has long been a careful observer of the phenomena of the planetary system, by means of telescopes of considera

ble size, and has contributed not a few interesting facts to astronomical science. He assures us that he has seen not only spots, but even mountains on the surface of Mercury, and that he succeeded in ascertaining the altitude of two of these mountains. One of them he found to be little more than 1000 toises in height, or about an English mile and 372 yards. The other measured 8900 toises, or ten miles and 1378 yards, which is more than four times higher than Mount Etna or the Peak of Teneriffe. The highest mountains are said to be situated in the southern hemisphere of this planet. The same observer informs us, that, by examining the variation in the daily appearance of the horns or cusps of this planet, when it appeared of a crescent form, he found the period of its diurnal rotation round its axis to be twenty-four hours, five minutes, and twenty-eight seconds. But these deductions require still to be confirmed by future observations.

The light or the intensity of solar radiation which falls on this planet is nearly seven times greater than that which fall upon the earth; for the proportion of their distances from the sun is nearly as three to eight, and the quantity of light diffused from a luminous body is as the square of the distance from that body. The square of 3 is 9, and the square of 8, 64, which, divided by 9, produces a quotient of 7 1-9, which nearly expresses the intensity of light on Mercury compared with that on the earth. Or, more accurately, thus: Mercury is 36,880,000 of miles from the sun, the square of which is 1,360,134,400,000,000: the earth is distant 95,000,000, the square of which is 9,025,000,000,000,000. Divide this last square by the first, and the quotient is about 6⅗, which is very nearly the proportion of light on this planet. As the apparent diameter of the sun is likewise in proportion to the square of the distance, the inhabitants of this planet will behold in their sky a luminous orb, giving light by day, nearly seven times larger than the sun appears to us; and every object on its surface will be illuminated with a brilliancy seven times greater than are the objects around us in a fine summer's day. Such a brilliancy of lustre on every object would completely dazzle our eyes in their present state of organization; but in every such case we are bound to believe that the organs of vision of the inhabitants of any world are exactly adapted to the sphere they occupy in the system to

which they belong. Were we transported to such a luminous world as Mercury, we could perceive every object with the same ease and distinctness we now do, provided the pupil of the eye, instead of being one eighth of an inch in diameter, as it now is, were contracted to the size of one fiftieth of an inch. In consequence of the splendour which is reflected from every object on this planet, it is likely that the whole scenery of nature will assume a most glorious and magnificent aspect, and that the *colours* depicted on the various parts of the scenery of that world will be much more *vivid* and *splendid* than they appear on the scenery of our terrestrial mansion; and since it appears highly probable that there are elevated mountains on this planet, if they be adorned with a diversity of colour, and of rural and artificial objects, they must present to the beholder a most beautiful, magnificent, and sublime appearance. The following figures will present to the eye a comparative view of the apparent size of the sun, as beheld from Mercury and from the earth.

Fig. VIII.



Diameter of the Sun as seen from Mercury.

Diameter of the Sun as seen from the Earth.

While the intensity of the solar light on this planet is about seven times greater than on the earth, the light on the surface of Uranus, the most distant planet of the system, is 360

times less than that on the earth; for the square of the earth's distance, as formerly stated, is 9,025,000,000,000,000, and the square of the distance of Uranus from the sun, 1,800,000,000 of miles, is 3,240,000,000,000,000,000, which, divided by the former number, gives a quotient of 359 and a fraction, or, in round numbers, 360; the number of times that the light on the earth exceeds that on Uranus. Yet we find that the light reflected from that distant planet, after passing 1,800,000,000 of miles from the body of the sun, and returning again by reflection 1,700,000,000 of miles to the earth, is visible through our telescopes, and even sometimes to the naked eye. Thus it appears that the intensity of light at the two extremes of the solar system is in the proportion of 2400 to 1; for $360 \times 6\frac{2}{3} = 2400$, the number of times that the quantity of light on Mercury exceeds that on Uranus. But we may rest assured, from what we know of the plans of Divine wisdom, that the eyes of organic intelligence, both at the extremes and in all the intermediate spaces of the system, are exactly adapted to the sphere they occupy and the quantity of light they receive from the central luminary.

In regard to the *temperature* of Mercury, if the intensity of *heat* were supposed to be governed by the same law as the intensity of light, the heat in this planet would, of course, be nearly seven times greater than on the earth. Supposing the average temperature of our globe to be fifty degrees of Fahrenheit's thermometer, the average temperature on Mercury would be 333 degrees, or 121 degrees above the heat of boiling water; a degree of heat sufficient to melt sulphur, to make nitrous acid boil, and to dissipate into vapour every volatile compound. But we have no reason to conclude that the degree of sensible heat on any planet is in an inverse proportion to its distance from the sun. We have instances of the contrary on our own globe. On the top of the highest range of the Andes, in South America, there is an intense cold at all times, and their summits are covered with perpetual snows, while in the plains immediately adjacent the inhabitants feel all the effects of the scorching rays of a tropical sun. The sun, during our summer in the northern hemisphere, is more than three millions of miles farther from us than in winter; and although the obliquity of his rays is partly the cause of the cold felt in winter when he is nearest us, yet it is not the *only* cause; for we find that the cold in New-York and Pennsyl

vania is more intense in winter than in Scotland, although the sun rises from ten to sixteen degrees higher above the horizon in the former case than in the latter. Besides, we find that the heat of summer in the southern hemisphere, *when the sun is nearest to the earth,* is not so great as in the summer of corresponding latitudes in the northern hemisphere. In short, did heat depend chiefly on the nearness of the sun or the obliquity of his rays, we should always have the same degree of heat or cold at the same time of the year, in a uniform circle; which experience proves to be contrary to fact. The degree of heat, therefore, on any planet, and on different portions of the same planet, must depend in part, and perhaps chiefly, on the nature of the atmosphere, and other circumstances connected with the constitution of the planet, in combination with the influence of the solar rays. These rays undoubtedly produce heat, but the degree of its intensity will depend on the nature of the substances on which they fall; as we find that the same degree of sensible heat is not felt when they fall on a piece of iron or marble as when they fall on a piece of wood or flannel.

Mercury was long considered as the smallest primary planet in the system; but the four new planets lately discovered between the orbits of Mars and Jupiter are found to be smaller. Its diameter is estimated at 3200 miles, and, consequently, its surface contains above 32,000,000 of square miles, and its solid contents are 17,157,324,800, or more than seventeen thousand millions of solid miles; and if the number of solid miles contained in the earth, which are 264,000,000,000, be divided by this sum, the quotient will be somewhat more than fifteen, showing that the earth is above fifteen times larger than Mercury. Notwithstanding the comparatively diminutive size of this planet, it is capable of containing a population upon its surface much greater than has ever been supported on the surface of the earth during any period of its history. In making an estimate on this point I shall take the population of England as a standard. England contains 50,000 square miles of surface, and 14,000,000 of inhabitants, which is 280 inhabitants for every square mile. The surface of Mercury contains 32,000,000 of square miles, which is not much less than all the habitable parts of our globe. At the rate of population now stated, it is therefore sufficiently ample to contain 8,960,000,000, or eight thousand nine hundred and

sixty millions of inhabitants, which is more than eleven times the present population of our globe. And although the one half of the surface of this planet were to be considered as covered with water, it would still contain nearly six times the population of the earth. Hence it appears, that small as this planet may be considered when compared with others, and seldom as it is noticed by the vulgar eye, it in all probability holds a far more distinguished rank in the intellectual and social system under the moral government of God, than this terrestrial world of which we are so proud, and all the living beings which traverse its surface.

I shall only mention further the following particulars in reference to this planet. In its revolution round the sun, its motion is swifter than that of any other planet yet discovered; it is no less than at the rate of 109,800 miles every hour at an average, although in some parts of its course it is slower, and in other parts swifter, since it moves in an elliptical orbit. Of course it flies 1830 miles every minute, and more than thirty miles during every beat of our pulse. The *density* of this planet is found by certain physical calculations and investigations, founded on the laws of universal gravitation, to be nine times that of water, or equal to that of lead; so that a ball of lead 3200 miles in diameter would exactly poise the planet Mercury. This density is greater than that of any of the other planets, and nearly twice the density of the earth. The *mass* of this planet, or the *quantity of matter* it contains, when compared with the mass of the sun, is, according to La Place, as 1 to 2,025,810, or about the two millionth part; that is, it would require two millions of globes of the size and density of Mercury to weigh one of the size and density of the sun. But as Mercury contains a much greater quantity of matter in the same bulk than the sun, *in point of size* it would require 22,000,000 of globes of the bulk of Mercury to compose a body equal to that of the sun. In consequence of the great density of this planet, bodies will have a greater weight on its surface than on the earth. It has been computed, that a body weighing one pound on the earth's surface would weigh one pound eight and a half drachms on the surface of Mercury. If the centrifugal force of this planet were suspended, and its motion in a circular course stopped, it would fall towards the sun, as a stone when thrown upward falls to the ground, by the force of gravity, with a velocity continually

increasing as the square of the distance from the sun diminished. The time in which Mercury or any other planet would fall to the sun by the centripetal force, or the sun's attraction, is equal to its periodic time divided by the square root of thirty-two; a principle deduced from physical and mathematical investigation. Mercury would therefore fall to the sun in 15 days, 13 hours; Venus in 39 days, 17 hours; the earth in 64 days, 13 hours; Mars in 121 days, 10 hours; Vesta in 205 days; Ceres in 297 days, 6 hours; Pallas in 301 days, 4 hours; Juno in 354 days, 19 hours; Jupiter in 765 days, 19 hours, or above two years; Saturn in 1901 days, or about five years; Uranus in 5425 days, or nearly fifteen years; and the Moon would fall to the earth, were its centrifugal force destroyed, in 4 days, 20 hours. Some of the deductions stated above may be apt to startle some readers as beyond the powers of limited intellects, and above the range of human investigation. The discoveries of Newton, however, have now taught us the laws by which these bodies act upon one another; and as the effects they produce depend very much upon the quantities of matter they contain, by observing these effects we are able, by the aid of mathematical reasoning, to determine the quantities of matter in most of the planets with considerable certainty. But to enter on the demonstrations of such points would require a considerable share of attention and of mathematical knowledge, and would probably prove tedious and uninteresting to the general reader.

Mercury revolves in an orbit which is elliptical, and more eccentric than the orbits of most of the other planets, except Juno, Ceres, and Pallas. Its *eccentricity*, or the distance of the sun from the centre of its orbit, is above 7,000,000 of miles. The time between its greatest elongations from the sun varies from 106 to 130 days. Its orbit is inclined to the ecliptic, or the plane of the earth's orbit, in an angle of seven degrees, which is more than double the inclination of the orbit of Venus.

II. OF THE PLANET VENUS.

Of all the luminaries of heaven, the sun and moon excepted, the planet Venus is the most conspicuous and splendid. She appears like a brilliant lamp amid the lesser orbs of night, and alternately anticipates the morning dawn and ushers in the evening twilight. When she is to the westward of the sun,

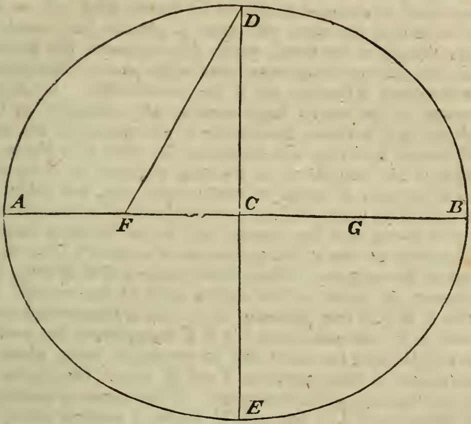
in winter, she cheers our mornings with her vivid light, and is a prelude of the near approach of the break of day and the rising sun. When she is eastward of that luminary, her light bursts upon us after sunset, before any of the other twinkling orbs of heaven make their appearance; and she discharges, in some measure, the functions of the absent moon. The brilliancy of this planet has been noticed in all ages, and has been frequently the subject of description and admiration both by shepherds and by poets. The Greek poets distinguished it by the name of *Phosphor* when it rose before the sun, and *Hesperus* when it appeared in the evening after the sun retired; and it is now generally distinguished by the name of the Morning and Evening Star.

> "Next Mercury, Venus runs her larger round,
> With softer beams and milder glory crown'd;
> Friend to mankind, she glitters from afar,
> Now the bright *evening*, now the *morning* star.
> From realms remote she darts her pleasing ray,
> Now leading on, now closing up the day;
> Term'd *Phosphor* when her *morning* beams she yields,
> And *Hesp'rus* when her ray the *evening* gilds."

Before proceeding to a more particular description of this planet, I shall lay before the reader a brief explanation of the nature of the planetary orbits, as I may have occasion to refer to certain particulars connected with them in the following descriptions. All the planets and their satellites move in elliptical orbits, more or less eccentric. The following figure exhibits the form of these orbits. (*See Fig. IX.*)

The figure *A D B E* represents the form of a planetary orbit, which is that of an oval or ellipse. The longest diameter is *A B;* the shorter diameter *D E*. The two points *F* and *G* are called the *foci* of the ellipse, around which, as two central points, the ellipse is formed. The sun is not placed in *C*, the centre of the orbit, but at *F*, one of the foci of the ellipse. When the planet, therefore, is at *A*, it is nearest the sun, and is said to be in its *perihelion;* its distance from the sun gradually increases till it reaches the opposite point, *B*, when it is at its greatest distance from the sun, and is said to be in its *aphelion;* when it arrives at the points *D* and *E* of its orbit, it is said to be at the *mean distance*. The line *A B*, which joins the perihelion and aphelion, is called the *line of the apsides*, and also the greater axis or the *transverse* axis of the orbit; *D E* is the *lesser* or *conjugate* axis; *F D*, the *mean*

FIG. IX.

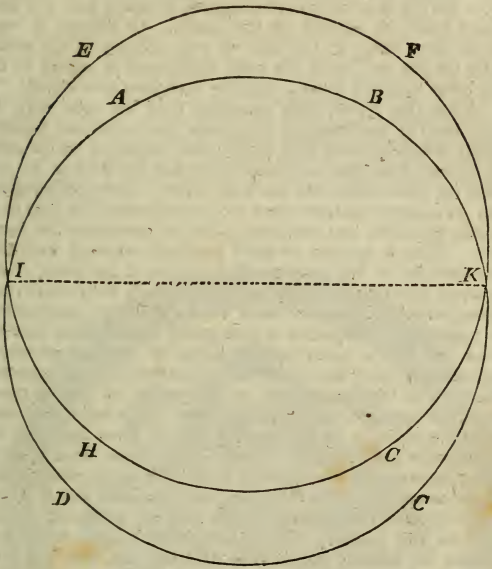


distance of the planet from the sun; *F C*, or *G C*, the *eccentricity* of the orbit, or the distance of the sun from its centre; *F* is the *lower focus*, or that in which the sun is placed; *G* the *higher focus*; *A* the *lower apsis*, and *B* the *higher apsis*. The orbits of some of the planets are more elliptical than others. The eccentricity of the orbit of Mercury is above 7,000,000 miles; that is, the distance from the point *F*, where the sun is placed, to the centre, *C*, measures that number of miles; while the eccentricity of Venus is only about 490,000 miles, or less than half a million. Most of the planetary orbits, except those of some of the new planets, approach very nearly to the circular form.

The orbits of the different planets do not all lie in the same plane, as they appear to do in orreries and in the representations generally given of the solar system. If we suppose a plane to pass through the earth's orbit, and to be extended in every direction, it will trace a line in the starry heavens which is called the *ecliptic*, and the plane itself is called the *plane of the*

ecliptic. The orbits of all the other planets do not lie in this plane, one half of each orbit rising above it, while the other half falls below it. This may be illustrated by supposing a large bowl or concave vessel to be nearly filled with water; the surface of the water will trace a circular line round the inner surface of the bowl, which may represent the ecliptic. while the surface of the water itself is the *plane* of the ecliptic, and the bowl is the one half of the concave sky. If we now immerse in the bowl a large circular ring obliquely, so that one half of it is above the surface of the water and the other half below, this ring will represent the orbit of a planet inclined to the ecliptic or to the fluid surface; or if we take two large rings or hoops of nearly equal size, and place the one within the other obliquely, so that the half of the one hoop may be above, and the opposite half below the other hoop, it will convey an idea of the inclination of a planet's orbit to the plane of the ecliptic. Thus, if the circle *E F G H* (Fig. X.) represent the plane of the earth's orbit or the ecliptic, the circle *A B C D* may represent the orbit of a planet which is in clined to it; the semicircle *I A B K* being below the level of the ecliptic, and the other half or semicircle being above it. The points of intersection at *I* and *K*, where the circles cut one another, are called the *nodes*. If the planet is moving in the direction *A I D*, the point *I*, where it ascends above the plane, is called the *ascending node*, and the opposite point, *K*, the *descending node*. The line *I K*, which joins the nodes, is called the *line of the nodes*, which, in the different planetary orbits, points to different parts of the heavens. It is when Mercury and Venus are at or near the line of the nodes that they appear to make a transit across the sun's disk. The moon's orbit is inclined to the plane of the earth's orbit in an angle of about five degrees; and it is only when the full moon or change happens at or near the *nodes* that an eclipse can take place, because the sun, moon, and earth are then nearly in the same plane; at all other times of full or change, the shadow of the moon falls either above or below the earth, and the shadow of the earth either above or below the moon. The ecliptic is supposed to be divided into twelve signs, or 360 degrees, which have received the following names:—*Aries*, *Taurus*, *Gemini*, *Cancer*, *Leo*, *Virgo*, *Libra*, *Scorpio*, *Sagittarius*, *Capricornus*, *Aquarius*, *Pisces*. Each of these signs is divided into thirty equal parts, called *degrees;* each

FIG. X.



degree into sixty parts, or minutes; each minute into sixty parts, or seconds, &c.

Having stated the above definitions, which it may be useful to keep in mind in our further discussions, I shall proceed to a particular description of the motions and other phenomena of Venus.

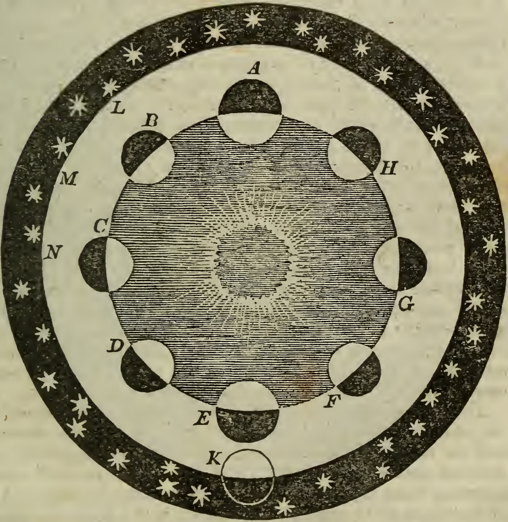
General Appearances and apparent Motions of Venus.—This planet, as already noticed, is only seen for a short time, either after sunset in the evening, or in the morning before sunrise. It has been frequently seen by means of the telescope, and sometimes by the naked eye, at noonday, but it was

never seen at midnight, as all the other planets may be, with the exception of Mercury. It never appears to recede farther from the sun than forty-seven degrees, or about half the distance from the horizon to the zenith. Of course, it was never seen rising in the east or even shining in the south after the sun had set in the west, as happens in regard to all the other heavenly bodies, with the exception now stated.

When this planet, after emerging from the solar rays, is first seen in the evening, it appears very near the horizon about twenty minutes after sunset, and continues visible only for a very short time, and descends below the horizon not far from the point where the sun went down. Every succeeding day its apparent distance from the sun increases; it rises to a higher elevation, and continues a longer time above the horizon. Thus it appears to move gradually eastward from the sun for four or five months, till it arrives at the point of its greatest elongation, which seldom exceeds forty-seven degrees, when it appears for some time stationary; after which it appears to commence a retrograde motion from east to west, but with a much greater degree of apparent velocity; approaching every day nearer the sun, and continuing a shorter time above the horizon, till, in the course of two or three weeks, it appears lost in the splendour of the solar rays, and is no longer seen in the evening sky till more than nine or ten months have elapsed. About eight or ten days after it has disappeared in the evening, if we look at the eastern sky in the morning, a little before sunrise, we shall see a bright star very near the horizon, which was not previously to be seen in that quarter; this is the planet Venus, which has passed its inferior conjunction with the sun, and has now moved to the westward of him, to make its appearance as the morning star. It now appears every succeeding day to move pretty rapidly from the sun to the westward, till it arrives at the point of its greatest elongation, between 45° and 48° distant from the sun, when it again appears stationary; and then returns eastward, with an apparently slow motion, till it is again immersed in the sun's rays, and arrives at its superior conjunction, which happens after the lapse of about nine months from the time of being first seen in the morning. But the planet is not visible to the naked eye all this time on account of its proximity to the sun when slowly approaching its superior conjunction. After passing this conjunction it

soon after appears in the evening, and resumes the same course as above stated. During each of the courses now described, when viewed with a telescope, it is seen to pass successively through all the phases of the moon, appearing *gibbous* or nearly round when it is first seen in the evening; of the form of a half moon when about the point of its greatest elongation; and of the figure of a crescent, gradually turning more and more slender as it approaches its inferior conjunction with the sun. Such are the general appearances which Venus presents to the attentive eye of a common observer, the reasons of which will appear from the following figure and explanations.

FIG. XI.

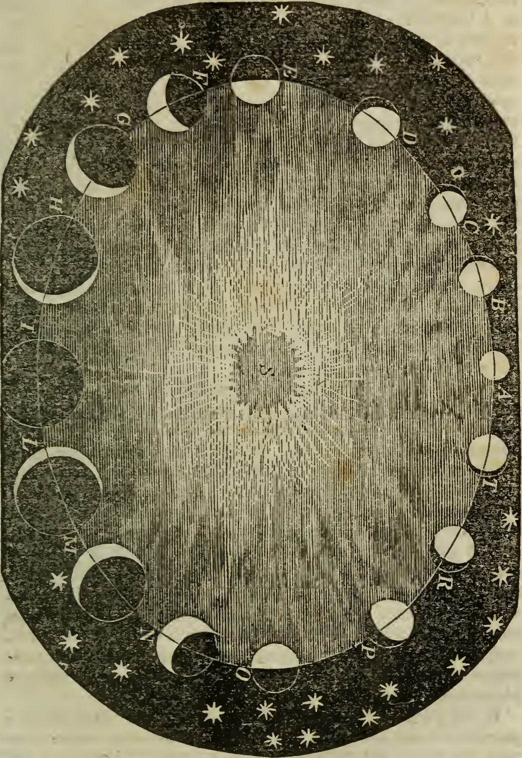


Let the earth be supposed at *K*; then when Venus is in G

the position marked A, it is nearly in a line with the sun as seen from the earth, in which position it is said to be in its *superior* conjunction with the sun, or beyond him, in the remotest part of its orbit from the earth; in which case the body of the sun sometimes interposes between the earth and Venus; at other times it is either a little above or below the sun, according as it happens to be either in north or south latitude. When it is in this position the whole of its enlightened hemisphere is turned towards the earth. As it moves on its orbit from A to B, which is from west to east, and is called its *direct* motion, it begins to appear in the evening after sunset. When it arrives at B, it is seen among the stars at L, in which position it assumes a gibbous phase, as a portion of its enlightened hemisphere is turned from the earth. When it arrives at C, it appears among the stars at M, at a still greater distance from the sun, and exhibits a less gibbous phase, approaching near to that of a half moon. When arrived at D, it is at the point of its greatest eastern elongation, when it appears like a half moon, and is seen among the stars at N; it now appears for some time stationary; after which it appears to move with a rapid course in an opposite direction, or from east to west, during which it presents the form of a crescent, till it approaches so near the sun as to be overpowered with the splendour of his rays. When arrived at E, it is said to be in its *inferior* conjunction, and, consequently, nearest the earth. In this position it is just 27 millions of miles from the earth; whereas, at its superior conjunction, it is no less than 163 millions of miles from the earth, for it is then farther from us by the whole diameter of its orbit, which is 136 millions of miles. This is the reason why it appears much smaller at its superior conjunction than when near its inferior; although, in the latter case, there is only a small crescent of its light presented to us, while in the former case its full enlightened hemisphere is turned to the earth.

The opposite figure (Fig. XII.) will exhibit more distinctly the *phases* of this planet in the different parts of its course, and the reason of the difference of its apparent magnitude in different points of its orbit. At A it is in the superior conjunction, when it presents to our view a round full face. At B it appears as an evening star, and exhibits a gibbous phase, somewhat less than a full moon. At D it approaches somewhat nearer to a half moon. At E, near the point of its

FIG. XII.



eastern elongation, it appears like a half moon. During all this course it moves from west to east. From F to I it appears to move in a contrary direction, from east to west,

during which it assumes the figure of a crescent, gradually diminishing in breadth, but increasing in extent, till it arrives at *I*, the point of its inferior conjunction, when its dark hemisphere is turned towards the earth, and is consequently invisible, being in a situation similar to that of the moon at the time of change. It is seen no longer in the evenings, but soon appears in the morning under the figure of a slender crescent, and passes through all the other phases represented in the diagram, at *M*, *N*, *O*, &c., till it arrives again at *A*, its superior conjunction. The earth is here supposed to be placed at *K*; and if it were at rest in that position, all the changes now stated would happen in the course of 224 days. But as the earth is moving forward in the same direction as the planet, it requires some considerable time before Venus can overtake the earth, so as to be in the same position as before with respect to the earth and the sun. The time, therefore, that intervenes between the superior conjunction and the same conjunction again is nearly 584 days, during which period Venus passes through all the variety of its motions and phases as a morning and evening star.

This diversity of motions and phases, as formerly stated, serves to prove the truth of the system, now universally received, which places the sun in the centre, and the earth beyond the orbit of Venus. In order to illustrate this point to the astronomical tyro in the most convincing manner, I have frequently used the following plan. With the aid of a planetarium, and by means of an ephemeris or a nautical almanac, I place the earth and Venus in their true positions on the planetarium, and then desire the learner to place his eye in a line with the balls representing Venus and the earth, and to mark the *phase* of Venus, as seen from the earth, whether gibbous, a half moon, or a crescent. I then adjust an equatorial telescope (if the observation be in the daytime), and, pointing it to Venus, show him this planet *with the same phase* in the heavens; an experiment which never fails to please and to produce conviction.

It has generally been asserted by astronomers that it is impossible to see Venus at the time of its superior conjunction with the sun. Mr. Benjamin Martin, in his "Gentleman and Lady's Philosophy," vol. i., says, "At and about her upper conjunction Venus cannot be seen, by reason of her nearness to the sun." And in his "Philosophia Britannica," vol. iii.,

the same opinion is expressed: "At her superior conjunction Venus would appear a full enlightened hemisphere, *were it not that she is then lost in the sun's blaze*, or hidden behind his body." Dr. Long, in his "Astronomy," vol. i., says, "Venus, in her superior conjunction, *if she could be seen*, would appear round like the full moon." Dr. Brewster, in the article *Astronomy* in the "Edinburgh Encyclopædia," when describing the phases of Mercury and Venus, says. "Their luminous side is completely turned to the earth at the time of their superior conjunction, when they would appear like the full moon, *if they were not then eclipsed by the rays of the sun*." The same opinion is expressed in similar phrases by Ferguson, Gregory, Adams, Gravesend, and most other writers on the science of astronomy, and has been copied by all subsequent compilers of treatises on this subject. In order to determine this point, along with several others, I commenced, in 1813, a series of observations on the celestial bodies *in the daytime*, by means of an equatorial instrument. On the 5th of June that year, a little before midday, when the sun was shining bright, I saw Venus distinctly with a magnifying power of sixty times, and a few minutes afterward with a power of thirty, and even with a power of fifteen times. At this time the planet was just 3° in longitude and about 13′ in time east of the sun's centre, and, of course, only $2\frac{3}{4}$° from the sun's limb. Cloudy weather prevented observations when Venus was nearer the sun.* On the 16th of October, 1819, an observation was made, in which Venus was seen when only six days and nineteen hours past the time of her superior conjunction. Her distance from the sun's eastern limb was then only 1° 28′ 42″. A subsequent observation proved that she could be seen when only 1° 27′ from the sun's margin, which approximates to the nearest distance from the sun

* The particulars connected with this observation, and with those made on the other planets, and on stars of the first and second magnitudes, together with a description of the instrument, and the manner of making day observations, are recorded in Nicholson's "Journal of Natural Philosophy," &c., for October, 1813, vol, xxxvi., p. 109–128, in a communication which occupies about twenty pages; and also, in an abridged form, in the "Monthly Magazine," "Annals of Philosophy," and other periodical journals of that period. During the succeeding winter the celebrated Mr. Playfair, professor of natural philosophy in the university of Edinburgh, communicated, in his lectures to the students, the principal details contained in that communication as *new facts* in astronomical science.

at which Venus is distinctly visible. About the tenth of March, 1826, I had a glimpse of this planet within a few hours of its superior conjunction, but the interposition of clouds prevented any particular or continued observations. It was then about 1° 25½′ from the sun's centre. Observations were likewise made to determine how near its *inferior* conjunction this planet may be seen. The following is the observation in which it was seen nearest to the sun. On March 11th, 1822, at thirty minutes past twelve, noon, the planet being only thirty-five hours past the point of its inferior conjunction, I perceived the crescent of Venus by means of an equatorial telescope, magnifying about seventy times. It appeared extremely slender, but distinct and well-defined, and apparently of a larger curve than that of the lunar crescent when the moon is about two days old. The difference of longitude between the sun and Venus at that time was about 2° 19′. A gentleman who happened to be present perceived the same phenomenon with the utmost ease and with perfect distinctness.*

From the above observations, the following conclusions are deduced: 1. That Venus may be distinctly seen at the moment of her superior conjunction, with a moderate magnifying power, when her geocentric latitude† at the time of conjunction exceeds 1½°, or, at most, 1° 43′. 2. That during the space of 584 days, or about nineteen months, the time Venus takes in moving from one conjunction of the sun to a like conjunction again, when her latitude at the time of her superior conjunction exceeds 1° 43′, she *may be seen by means of an equatorial telescope every clear day without interruption*, except at the moment of her inferior conjunction, and a very short time before and after it, a circumstance which cannot be affirmed of any other celestial body, the sun only ex-

* The observations stated above are also recorded in scientific journals. The observation of the 16th October, 1819, is recorded in the "Edinburgh Philosophical Journal," No. V., for July, 1820, p. 191, 192; and in Dr. Brewster's *second* edition of "Ferguson's Astronomy," vol. ii., p. 111; in the "Monthly Magazine" for August, 1820, vol. i., p. 62. The observation of March 11, 1822, made on Venus when near the *inferior* conjunction, is recorded at large in the "Edinburgh Philosophical Journal," No. XIII., July, 1822, p. 177, 178, &c.

† The *latitude* of a heavenly body is its distance from the ecliptic, or the apparent path of the sun, either north or south. Its *geocentric* latitude is its latitude as seen from the earth. Its *heliocentric* latitude is its latitude as viewed from the sun. These latitudes seldom coincide.

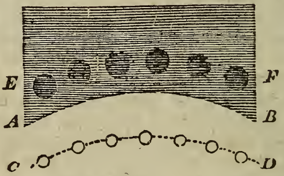
cepted. 3. That from the time when Venus ceases to be visible, prior to her inferior conjunction, on account of the smallness of her crescent and her proximity to the sun, to the moment when she may again be perceived in the day time by an equatorial telescope, there elapses a period of only two days and twenty-two hours; or, in other words, Venus can never be hidden from our view about the time of her inferior conjunction for a longer period than seventy hours. 4. That, during the space of 584 days, the longest period in which Venus can be hidden from our view under any circumstances, excepting a cloudy atmosphere, is about sixteen days and a half. During the same period, this planet sometimes will be hidden from the view of a common observer for the space of five or six months.

One practical use of the above observations is, that they may lead to the determination of the difference (if any) between the polar and equatorial diameters of this planet, which point has never yet been determined. It is well known that the earth is of a spheroidal figure, having its polar shorter than its equatorial diameter. Jupiter, Mars, and Saturn have also been ascertained to be oblate spheroids, and the proportion between their equatorial and polar diameters has been pretty accurately determined. As Venus is found to have a rotation round her axis, as these planets have, it is reasonable to conclude that she is of a similar figure. It is impossible, however, to determine this point when she is in those positions in which she has generally been viewed; as at such times she assumes either a gibbous phase, the form of a half moon, or that of a crescent, in neither of which cases can the two diameters be measured. I am therefore of opinion that, at some future conjunction, when her geocentric latitude is considerable, with a telescope of a high magnifying power, furnished with a micrometer, this point might be ascertained. If the planet is then viewed at a high latitude, and the sky serene, its disk will appear sufficiently luminous and well defined for this purpose; free of that glare and tremulous aspect it generally exhibits when near the horizon, which makes it appear larger than it ought to do, and prevents its margin from being accurately distinguished.

Such observations require a considerable degree of attention and care, and various contrivances for occasionally diminishing the aperture of the object glass, and for preventing

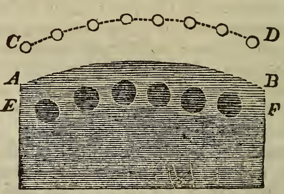
the direct rays of the sun from entering the tube of the telescope. In order to view this planet to advantage at any future conjunction, when in *south* latitude, it will be proper to fix a board, or any other thin opaque substance, at a considerable distance beyond the object end of the telescope, having such a degree of concave curvature as shall nearly correspond with a segment of the diurnal arc at that time described by the sun, with its lower concave edge at an elevation a small degree above the line of collimation of the telescope, when adjusted for viewing the planet, in order to intercept as much as possible the solar rays. When the planet is in *north* latitude, the curvature of the board must be made *convex*, and placed a little below the line of sight.

Fig. XIII.



The above figure will illustrate my idea; where *A B* (Fig. XIII.) represents the concave curve of the board to be used when the planet is in south latitude; *C D*, a segment of the apparent diurnal path of the planet; and *E F*, a segment of the sun's diurnal arc. Fig. XIV. represents the board to be used when

Fig. XIV.



the planet is in *north* latitude, which requires no further description.

I have given the above brief statement of the observations on Venus because they are not yet generally known, and because compilers of elementary books on astronomy still reiterate the vague and unfounded assertion that it is impossible to see this planet at its superior conjunction, when it presents a full enlightened hemisphere. The circumstance now ascertained may not be considered as a fact of much importance in astronomy. It is always useful, however, in every department of science, to ascertain every fact connected with its principles, however circumstantial and minute, as it tends to give precision to its language; as it enables the mind to take into view every particular which has the least bearing on any object of investigation; and as it may ultimately promote its progress by leading to conclusions which were not at first apprehended. One of these conclusions or practical uses has been stated above; and another conclusion is, that such observations as now referred to may possibly lead to the discovery of planets yet unknown within the orbit of Mercury, which circumstance I shall take occasion more particularly to explain in the sequel.

Discoveries made by the telescope in relation to Venus.—The first circumstance which attracted the attention of astronomers after the invention of the telescope was, the variety of phases which Venus appeared to assume, of which I have already given a description. Nothing further was observed to distinguish this planet till more than half a century had elapsed, when Cassini, a celebrated French astronomer, in the years 1666–7, discovered some spots on its surface, by which he endeavoured to ascertain the period of its revolution round its axis. October 14th, 1666, at five hours forty-five minutes, P. M., he saw a bright spot near the limits between the light and the dark side of the planet, not far from its centre; at the same time he noticed two dark oblong spots near the west side of the disk, as represented, Fig. XV. After this he could obtain no satisfactory views of Venus till April 20th, 1667, about fifteen minutes before sunrise, when he saw upon the disk, now half enlightened, a bright part, distant from the southern edge about a fourth part of the diameter of the disk, and near the eastern edge. He saw, likewise, a darkish oblong spot towards the northern edge, as in Fig. XVI. At sun-

rise he perceived that the bright part was advanced farther from the southern point than when he first observed it, as at Fig. XVII., when he had the satisfaction of finding an evident proof of the planet's motion. On the next day, at sunrise, the bright spot was a good way off the section, and distant from

Fig. XV. Fig. XVI.

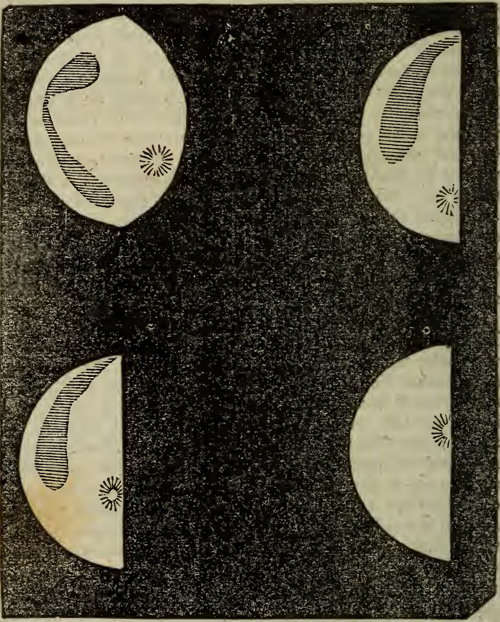


Fig. XVII. Fig. XVIII.

the southern point a fourth part of the diameter of the disk. When the sun had risen six degrees above the horizon the spot had got beyond the centre. When the sun had risen seven degrees the section cut it in halves, as in Fig. XVIII.

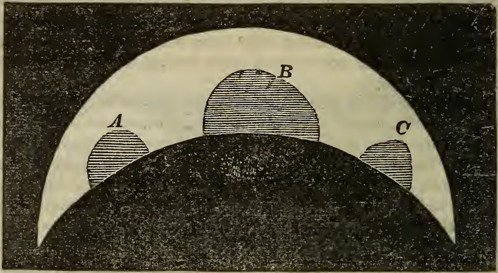
which showed its motion to have some inclination towards the centre.* Several observations of a similar kind were made about that time, which led Cassini to the conclusion that the planet revolves about its axis in a period somewhat more than twenty-three hours. From this time, for nearly sixty years, we have no further accounts of spots having been observed on the disk of Venus.

In the year 1726, *Bianchini*, with telescopes of 90 and 100 Roman palms, commenced a series of observations on Venus, and published an account of them in a book entitled, "*Hesperi et Phosphori nova Phenomena.*" In these observations we do not find that any one of them was continued long enough to discover any change of position in the spots at the end of the observation from what there was at the beginning; but at the distance of two and of four days he found the same spot advanced so far that he concluded it must have gone round at the rate of 15° in a day. This advance would show that Venus turned round either once in about twenty-four days or in little more than twenty-three hours, but would not determine which of these was the true period. For, if an observer at a given hour, suppose seven in the evening, were to mark the exact place of a spot, and at the same hour on the next day find the spot advanced 15°, he would not be able to determine whether the spot, during that interval of twenty-four hours, had advanced forward only 15°, or had finished a revolution, and 15° more as part of another rotation.† Of these two periods Bianchini concluded that the rotation was accomplished in twenty-four days, eight hours. The following is the chief, if not the only observation, he brings forward to substantiate his conclusion. He saw three spots, *A*, *B*, *C*, in the situation represented in Fig. XIX., which he and several persons of distinction viewed for about an hour, when they could discover no change of place in their appearance. Venus being hidden behind the Barbarini palace, their view was interrupted for nearly three hours, at the end of which they found that the spots had not sensibly changed their situation. But the inference from this observation is not conclu-

* See "Philosophical Transactions," abridged by Drs. Hutton, Shaw, and Pearson, vol. i., part ii., p. 217; "Journal *des Savans*," vol. i., p. 210; and "*Memoires* of the Royal Academy of Sciences"

† See some particular remarks on this subject, illustrated with a figure, in my volume "On the Improvement of Society," section iii.

Fig. XIX.



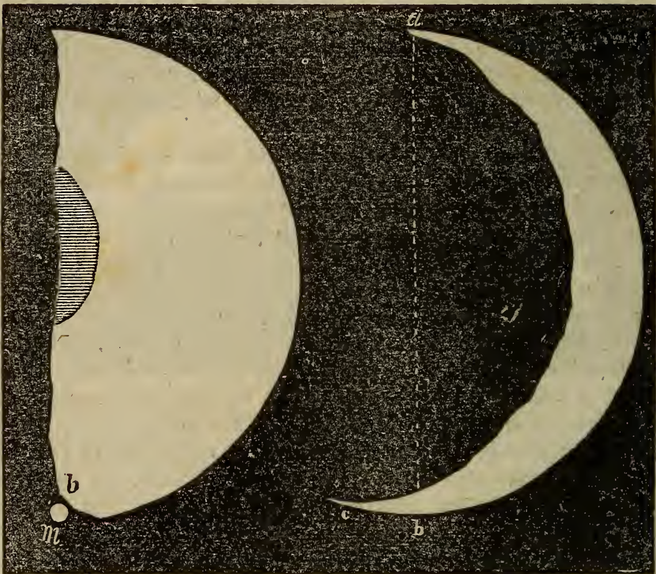
sive for the period of twenty-four days eight hours. For, during the three hours' interruption, the spot *C* might have gone off the disk, and the spot *B* moved into its place, where, being near the edge, it would appear less than when in the middle; *A*, succeeding into the place of *B*, would appear larger than it did near the edge, and another spot might have come into the place of *A*. For that there were other spots, particularly one, which, by the rotation of Venus, would have been brought into the place of *A*, appears by the figures given by Bianchini; and, if so, it would correspond with the rotation of twenty-three hours twenty minutes deduced by Cassini. Besides, it is impossible to make observations on Venus for three or four hours in succession, as is here supposed, without the help of equatorial instruments, which were not then in use, as this planet is seldom more than three hours above the horizon after sunset; and when it descends within 8° or 10° of the horizon, it is impossible to see its surface with any degree of distinctness, on account of the brilliancy of its light and the undulating vapours near the horizon, which, in some cases, prevent even its phase from being accurately distinguished. In the communication in "Nicholson's Journal" for 1813, already referred to, I have shown how the dispute in reference to the rotation of Venus may be settled by commencing a series of observations on this planet in the daytime, when its spots, if any were perceived, could be traced in their

motion for twelve hours or more. Mr. Ferguson, in his astronomy, by adopting the conclusion of Bianchini, has occupied a number of pages in describing the phenomena on Venus on this supposition, which description is altogether useless, and conveys erroneous ideas of the circumstances connected with this planet, if the period determined by Cassini (as is most probable) be correct.

Mr. Schroeter, formerly mentioned, who has been a most diligent and accurate observer of the heavens, commenced a series of observations in order to determine the daily period of this planet. He observed particularly the different shapes of the two horns of Venus. Their appearance generally varied in a few hours, and became nearly the same at the corresponding time of the subsequent day, or, rather, about half an hour sooner every day. Hence he concluded that the period must be about twenty-three hours and a half; that the equator of the planet is considerably inclined to the ecliptic, and its pole at a considerable distance from the point of the horn. From several observations of this kind he found that the period of rotation must be twenty-three hours, twenty-one minutes, or only one minute more than had been assigned by Cassini; and this, we have reason to believe, is about the true period of this planet's revolution round its axis, being thirty-five minutes less than the period of the earth's rotation, which is twenty-three hours, fifty-six minutes. I have stated these observations respecting the rotation of Venus at some length, because they are not generally known to common readers on this subject, or noticed in modern elementary books on astronomy, and that the general reader may perceive the reason of the dispute which has arisen among astronomers on this point.

Mountains on Venus.—Mr. Schroeter, in his observations, discovered several mountains on this planet, and found that, like those of the moon, they were always highest in the southern hemisphere; their perpendicular heights being nearly as the diameters of their respective planets. From the 11th of December, 1789, to the 11th of January, 1790, the southern horn, *b* (Fig. XX.), appeared much blunted, with an enlightened mountain, *m*, in the dark hemisphere, which he estimated at about 18,300 toises, or nearly twenty-two miles, in perpendicular height. It is quite obvious that if such a bright spot as here represented was regularly or periodically seen, it must indicate a very high elevation on the surface of the

FIG. XX. FIG XXI.



planet, and its precise height will depend upon its distance from the illuminated portion of the disk, or, in other words, the length of its shadow. It is precisely in such a way that the mountains in the moon are distinguished. Mr. Schroeter measured the altitude of other three mountains, and obtained the following results: Height of the first, nineteen miles, or about five times the height of Chimborazo; height of the second, eleven miles and a half; and of the third, ten miles and three quarters. These estimates may, perhaps, require certain corrections in future observations.

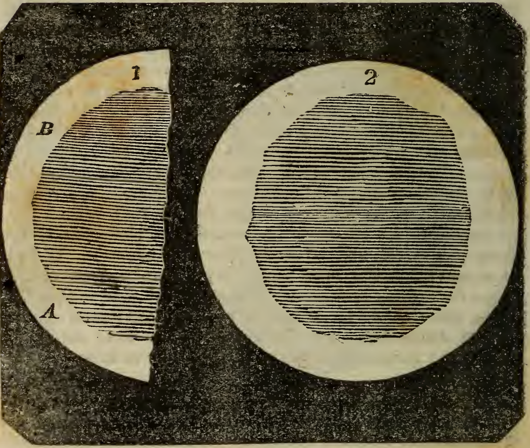
Atmosphere of Venus.—From several of Mr. Schroeter's observations, he concludes that Venus has an atmosphere of considerable extent. On the 10th of September, 1791, he observed that the southern cusp of Venus disappeared, and was bent like a hook about eight seconds beyond the luminous semicircle into the dark hemisphere. The northern cusp had the same tapering termination, but did not encroach upon the dark part of the disk. A streak, however, of glimmering

bluish light proceeded about eight seconds along the dark line, from the point of the cusp, from b to c (Fig. XXI.), b being the extremity of the diameter of a b, and, consequently, the natural termination of the cusp. The streak b c, verging to a pale gray, was faint when compared with the light of the cusp at b. I was struck with a similar appearance when observing Venus, when only thirty-five hours past her inferior conjunction, on March 11, 1822, as formerly noticed (p. 84). One of the cusps, at least, appeared to project into the dark hemisphere, like a fine lucid thread, beyond the luminous semicircle. This phenomenon Mr. Schroeter considers as the *twilight*, or crepuscular light of Venus. From these and various other observations, which it would be too tedious to detail, he concludes, on the ground of various calculations, that the *dense* part of the atmosphere of Venus is about 16,020 feet, or somewhat above three miles high; that it must rise far above the highest mountains; that it is more opaque than that of the moon; and that its density is a sufficient reason why we do not discover on the surface of Venus those superficial shades and varieties of appearance which are to be seen on the other planets.

Day Observations on Venus.—The most distinct and satisfactory views I have ever obtained of this planet were taken at noonday, or between the hours of ten in the morning and two in the afternoon, when it happened to be at a high elevation above the horizon, which is generally the case during the summer months. The light of this planet is so brilliant, that its surface and margin seldom appear well defined in the evening, even with the best telescopes. But in the daytime its disk and margin present a sharp and well-defined aspect with a good achromatic telescope, and almost completely free of those undulations which obscure its surface when near the horizon. The following figure (No. 1) represents one of the appearances of Venus which I have frequently seen in the daytime when viewing this planet at a high altitude and in a serene sky, when near the meridian, by means of a three-and-a-half feet achromatic telescope, magnifying about 150 times.

The exterior curve of the planet, as here exhibited, appeared far more lucid and bright than the interior portion. It was not a mere stripe or luminous margin, but a broad semicircle, of a breadth nearly one third of the semidiameter of the planet. It appeared as if it were a kind of table-land, or a

Fig. XXII.



more elevated portion of the planet's surface, while the interior and darker part appeared more like a plain, diversified with inequalities, and two large spots, somewhat darker than the other parts, were faintly marked. The appearance was somewhat similar to that of certain portions of the level parts of the moon which lie adjacent to a ridge of mountains or a range of elevated ground. I have exhibited this view of Venus at different times to various individuals, and even those not accustomed to look through telescopes could plainly perceive it I consider it as a corroboration of the fact, that mountains of great elevation exist on the surface of this planet. There appeared likewise some slight indentations in the boundary which separated the dark from the enlightened hemisphere, which circumstance leads to the same conclusion. If the whole hemisphere of the planet had been enlightened, it would probably have appeared as in No. 2. On the whole, I am of opinion that future discoveries in relation to Venus will be chiefly made in the daytime, by large telescopes

adapted to equatorial machinery, when such instruments shall be brought into use more than they have hitherto been. Venus, however, is the only planet on which useful observations can be made in the daytime ; for although several of the other planets can be perceived, even at noonday, particularly Jupiter, yet they present a very obscure and cloudy appearance compared with Venus, on account of the comparatively small quantity of solar light which falls upon their surfaces.

Supposed Satellite of Venus.—Several astronomers have been of opinion that Venus is attended with a satellite, although it is seldom to be seen. It may not be improper to give the reader an abridged view of the observations on which this opinion is founded, that he may be able to judge for himself. The celebrated Cassini, who discovered the rotation of Mars, Jupiter, and Venus, and four of the satellites of Saturn, was the first who broached this opinion. The following is his account of the observations on which it is founded :—

"1686, August 18, at fifteen minutes past four in the morning, looking at Venus with a telescope of thirty-four feet, I saw at the distance of three fifths of her diameter, eastward, a luminous appearance, of a shape not well defined, that seemed to have the same phase with Venus, which was then gibbous on the western side. The diameter of this phenomenon was nearly equal to a fourth part of the diameter of Venus. I observed it attentively for a quarter of an hour, and, having left off looking at it for four or five minutes, I saw it no more ; but daylight was then advanced. I had seen a like phenomenon, which resembled the phase of Venus, on January 25th, 1672, from fifty-two minutes after six in the morning to two minutes after seven, when the brightness of the twilight caused it to disappear. Venus was then horned, and this phenomenon, the diameter of which was nearly a fourth part of the diameter of Venus, was of the same shape. It was distant from the southern horn of Venus a diameter of Venus on the western side. In these two observations I was in doubt whether it was not a satellite of Venus, of such a consistence as not to be very well fitted to reflect the light of the sun, and which, in magnitude, bore nearly the same proportion to Venus as the moon does to the earth, being at the same distance from the sun and the earth as Venus was, the phases of which it resembled."

In the year 1740, October 23, at sunrise, Mr. Short, with

a reflecting telescope of sixteen inches and a half, which magnified about sixty times, perceived a small star at the distance of about ten seconds from Venus; and, putting on a magnifying power of 240 times, he found the star put on the phase of Venus. He tried another magnifying power of 140 times, and even then found the star to have the same phase. Its diameter seemed about a third of the diameter of Venus. Its light was not so bright or vivid, but exceedingly sharp and well defined. A line passing through the centre of Venus and it made an angle with the equator of about twenty degrees. He saw it, for the space of an hour, several times that morning; but, the light of the sun increasing, he lost it about a quarter of an hour after eight. He says he looked for it every clear morning after this, but never saw it again.*

A similar phenomenon is described as having been seen by Baudouin, Montaigne, Rodkier, Montbarron, and other astronomers, and, from their observations, the celebrated M. Lambert, in the "Memoirs of the Academy of Berlin" for 1773, gave a theory of the satellite of Venus, in which he concludes that its period is eleven days, five hours, and thirteen minutes; the inclination of its orbit to the ecliptic, $63\frac{3}{4}°$; its distance from Venus, $66\frac{1}{2}$ radii of that planet; and its magnitude, 4-27 of that of Venus, or nearly equal to that of our moon. There is a singular consistency in these observations, which it is difficult to account for if Venus have no satellite. Astronomers expected that such a body, if it existed, would be seen as a small dark spot upon the sun at the time of the transits of Venus in 1761 and 1769; but no such phenomenon seems to have been noticed at those times by any of the observers. Lambert, however, maintains, from the tables he calculated in relation to this body, that the satellite, if it did exist, might not have passed over the sun's disk at the time of the transits, but he expected that it might be seen alone on the sun when Venus passed near that luminary.

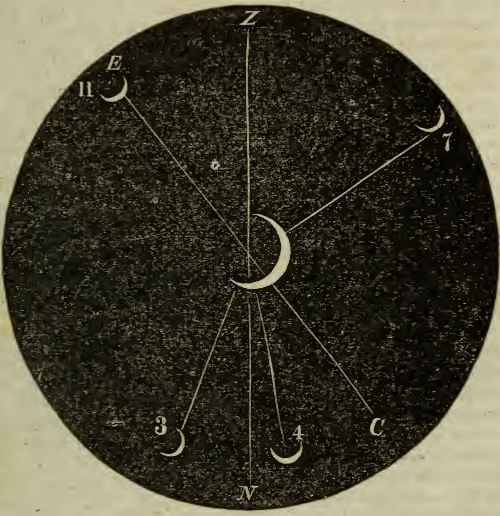
The following is a particular account of the observations made by Mr. Montaigne:—May 3, 1760, he perceived, at twenty minutes distances from Venus, a small crescent, with the horns pointing the same way as those of Venus. Its di-

* "Philosophical Transactions," No. 459, for January, February, and March, 1741.

ameter was a fourth of that of its primary; and a line drawn from Venus to the satellite made, below Venus, an angle with the vertical of about twenty degrees towards the south, as in Fig. XXII., No. 3, where $Z\ N$ represents the vertical, and $E\ C$

Fig. XXII.—No 3.

North.

West  *East.*

South.

a parallel to the ecliptic, making then an angle with the vertical of forty-five degrees. The numbers 3, 4, 7, 11 mark the situations of the satellite on the respective days. May 4th, at the same hour, he saw the same star, distant from Venus about one minute more than before, and making an angle with the vertical of ten degrees below, but on the north side; so that the satellite seemed to have described an arc of about thirty

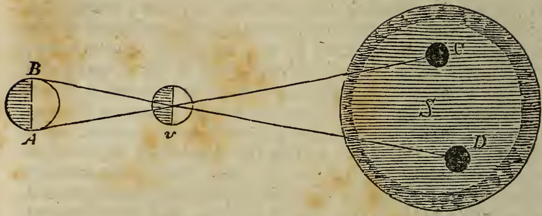
degrees, whereof Venus was the centre, and the radius twenty minutes. The two following nights being hazy, Venus could not be seen. But May 7th, at the same hour as on the preceding days, he saw the satellite again, but above Venus, and on the north side, as represented at 7, between twenty-five and twenty-six minutes, upon a line which made an angle of forty-five degrees with the vertical towards the right hand. It appears by the figure that the points 3 and 7 would have been diametrically opposite if the satellite had gone fifteen degrees more round the central point where Venus is represented May 11th, at nine o'clock P. M., the only night when the view of the planet was not obscured by moonlight, twilight, or clouds, the satellite appeared nearly at the same distance from Venus as before, making with the vertical an angle of forty-five degrees towards the south, and above its primary. The light of the satellite was always very weak; but it had always the same phase with its primary, whether viewed with it in the field of the telescope or alone by itself. He imagined that the reason why the satellite had been so frequently looked for without success might be, that one part of its globe was crusted over with spots, or otherwise unfit to reflect the light of the sun with any degree of brilliancy, as is supposed to be the case with the fifth satellite of Saturn.

It is evident that, if Venus have a satellite, it must be difficult to be seen, and can only be perceived in certain favourable positions. It cannot be seen when nearly the whole of its enlightened hemisphere is turned to the earth, on account of its great distance at such a time, and its proximity to the sun; nor could it be expected to be seen when the planet is near its inferior conjunction, as it would then present to the earth only a very slender crescent, besides being in the immediate neighbourhood of the sun. The best position in which such a body might be detected is near the time of the planet's greatest elongation, and when it would appear about half enlightened. If the plane of its orbit be nearly coincident with the plane of the planet's orbit, it will be frequently hidden by the interposition of the body of Venus, and likewise when passing along her surface in the opposite point of its orbit; and if one side of this body be unfitted for reflecting much light, it will account in part for its being seldom seen. It is not sufficient in this case to say, as Sir David Brewster has done, "that Mr. Wargentin had in his possession

a good achromatic telescope, which always showed Venus with such a satellite, and that the deception was discovered by turning the telescope about its axis." For we cannot suppose that such accurate observers as those mentioned above would have been deceived by such an optical illusion; and, besides, the telescopes which were used in the observations alluded to were both refractors and reflectors, and it is not likely that both kinds of instruments would produce an illusion, especially when three different powers were applied, as in Mr. Short's observations. Were the attention of astronomers more particularly directed to this point than it has hitherto been; were the number of astronomical observers increased to a much greater degree than at present; and were frequent observations on this planet made in the clear and serene sky of tropical climes, it is not improbable that a decisive opinion might soon be formed on this point; and, if a satellite were detected, it would tend to promote the progress and illustrate the deductions of physical astronomy. It is somewhat probable, reasoning *à priori*, that Venus, a planet nearly as large as the earth, and in its immediate neighbourhood, is accompanied by a secondary attendant.

Transits of Venus.—This planet, when in certain positions, is seen to pass like a round black spot across the disk of the sun. These *transits*, as they are called, are of rare occurrence, and take place at intervals of 8 and of 113 years. If the plane of the orbit of Venus exactly coincided with that of the earth, a transit would happen at regular intervals of little more than nineteen months: but as one half of this planet's orbit is three degrees and a half below the plane of the earth's orbit, and the other half as much above it, a transit can only take place when it happens to be in one of the *nodes*, or intersections of the orbits, about the time of its inferior conjunction. These transits of Venus are phenomena of very great importance in astronomy, as it is owing to the observations which have been made on them, and the calculations founded on these observations, that the distance of the sun has been very nearly ascertained, and the dimensions of the planetary system determined to a near approximation to the truth. It would be too tedious to enter into a particular explanation of the process and calculations connected with this subject, and therefore I shall only, in a few words, explain the *principle* on which the deductions are founded. Suppose *B A* (Fig. XXIII.)

FIG. XXIII.



to represent the earth; v, Venus; and S the sun. Suppose two spectators, A and B, at opposite extremities of that diameter of the earth which is perpendicular to the ecliptic; then, at the moment when the observer at B sees the centre of the planet projected at D, the observer at A will see it projected at C. If, then, the two observers can mark the precise position of Venus on the sun's disk at any given moment, or note the precise time of ingress or egress of the planet, the angular measure of $C\ D$, as seen from the earth, might be ascertained. Since $A\ C$ and $B\ D$ are straight lines crossing each other at v, they consequently make equal angles on each side of the point v; and $C\ D$ will be to $B\ A$ as the distance of Venus from the sun is to her distance from the earth; that is, as 68 to 27, or nearly as 2 1-2 to 1: for Venus is 68 millions of miles from the sun, and 27 millions from the earth, at the time of a transit or an inferior conjunction. $C\ D$, therefore, occupies a space on the sun's disk 2 1-2 times as great as the earth's apparent diameter at the distance of the sun; or, in other words, it is equal to *five times* the sun's horizontal parallax; and, therefore, any error that might occur in measuring it will amount to only one fifth of that error on the horizontal parallax that may be deduced from it; and it is on the ground of this parallax that the distance of the sun is determined. The result of all the observations made on the transits which happened in 1761 and 1769 gives about 8 1-2 seconds as the horizontal parallax of the sun, which makes his distance 95 millions of miles. This distance is considered by the most enlightened astronomers as within *one fiftieth* part of the true distance of the sun from the earth; so

that no future observations will alter this distance so as to increase or diminish it by more than two millions of miles.

The future transits of Venus for the next 400 years are as follow :—

	hours.	minutes.	
1874, December 9th ...	4	8	A.M.
1882, December 6th ...	4	16	P.M.
2004, June 8th	8	51	A.M.
2012, June 6th	1	17	A.M.
2117, December 11th .	2	57	A.M.
2125, December 8th ...	3	9	P.M.
2247, June 11th	0	21	P.M.
2255, June 9th	4	44	A.M.

Some of these transits will last nearly seven hours. The next two transits will not be visible throughout their whole duration in Britain or in most countries in Europe. Such was the importance attached to the observations of the last transits in 1761 and 1769, that several of the European states fitted out expeditions to different parts of the world, and sent astronomers with them to make the requisite observations. This was one end, among others, of the celebrated expedition of Captain Cook, in 1769, to the islands of the Pacific Ocean; and the transit was observed in *Tahiti*, now so celebrated on account of the moral revolution which has lately taken place among its inhabitants.

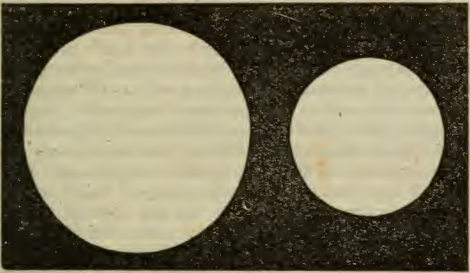
Magnitude, and Extent of Surface on this Planet.—The diameter of Venus has been computed at about 7800 miles; and, consequently, its surface contains 191,134,944, or above 191 millions of square miles. Taking, as formerly, the population of England as a standard, this planet would contain a number of inhabitants equal to more than 53,500 millions, or nearly sixty-seven times the population of our globe. It does not appear that any great quantity of water exists upon this planet, otherwise there would be a greater contrast between the different parts of its surface, the water presenting a much darker hue than the land. For, if from a high mountain we survey a scene in which a portion of a large river or of the ocean is contained, when the sun is shining on all the objects, we shall find that the water presents a much darker appearance than the land, as it absorbs the greater part of the rays of light, except in a few points between our eyes and

the sun, where his rays are reflected from the surface of the fluid; but these partial reflections would be altogether invisible at the distance of the nearest planet. It is pretty evident, however, from what has been formerly stated, that there is a great diversity of surface on this planet; and if some of its mountains be more than twenty miles in elevation, they may present to view objects of sublimity and grandeur, and from their summits extensive and diversified prospects, of which we can form no adequate conception. So that Venus, although a small fraction smaller than the earth, may hold a rank in the solar system and in the empire of the Almighty, in point of population and sublimity of scenery, far surpassing that of the world in which we dwell.

Having dwelt so long on the phenomena of this planet, I shall state only the following additional particulars: The *quantity of light* on Venus is nearly twice as great as that on the earth, which will, doubtless, have the effect of causing all the colours reflected from the different parts of the scenery of that planet to present a more vivid, rich, and magnificent appearance than with us. It is probable, too, that a great proportion of the objects on its surface are fitted to reflect the solar rays with peculiar splendour; for its light is so intense as to be distinctly seen by telescopes in the daytime; and, during night, the eye is so overpowered by its brilliancy as to prevent its surface and margin from being distinctly perceived. Were we to indulge our imaginations on this subject, this circumstance might lead us to form various conceptions of the glory and magnificence of the diversified objects which may be presented to the view of the intellectual beings who inhabit this world; but, in the mean time, we have no sufficient *data* to warrant us in indulging in conjectural speculations. The apparent size of the sun as seen from Venus, compared with his magnitude as seen from the earth, is represented in the opposite figure, the larger circle showing the size of the sun from Venus.

With regard to the *heat* in this planet, according to the principles and facts formerly stated (page 70), it may be modified by the constitution of its atmosphere and the nature of the substances which compose its surface, so that its intensity may not be so great as we might imagine from its nearness to the sun. Even on the supposition that the intensity of the heat of any body is inversely as the square of its distance

FIG. XXIV



from the sun, it has been calculated that the greatest heat in Venus exceeds the heat of St. Thomas, on the coast of Guinea, or of Sumatra, about as much as the heat in those places exceeds that of the Orkney Islands or that of the city of Stockholm ; and, therefore, at 60 degrees north latitude on that planet, if its axis were perpendicular to the plane of its orbit, the heat would not exceed the greatest heat of the earth, and, of course, vegetation like ours could be carried on, and animals of a terrestrial species might subsist. But we have no need to enter into such calculations in order to prove the habitability of Venus, since the Creator has, doubtless, in this as well as in every other case, adapted the structure of the inhabitant to the nature of the habitation.

In addition to the above, the following facts may be stated : Venus revolves in an orbit which is 433,800,000 of miles in circumference in the space of 224 days 16 hours ; its rate of motion is therefore about eighty thousand miles every hour, one thousand three hundred and thirty miles every minute, and above twenty-two miles every second. Its distance from the sun is 68 millions of miles ; and its distance from the earth, when nearest us, is about 27 millions of miles, which is the nearest approach that any of the heavenly bodies (except the moon) make to the earth. Yet this distance, when considered by itself, is very great ; for it would require a cannon ball six years and three months to move from the earth to the nearest point of the orbit of Venus, although it were flying every moment at the rate of 500 miles an hour, or

12,000 miles a day. Were the enlightened hemisphere of the planet turned to the earth when it is in this nearest point of its orbit, it would appear like a brilliant moon, twenty-five times larger than it generally does to the naked eye; but at that time its bright side is turned to the sun and away from the earth. At its greatest distance from us it is 163 millions of miles from the earth. The period of its *greatest brightness* is when it is about forty degrees from the sun, either before or after its inferior conjunction, at which time there is only about *one fourth* part of its disk that appears enlightened. In this position it may sometimes be seen with the naked eye even amid the splendours of noonday. In the evening it casts a distinct shadow on a horizontal plane. Sir John Herschel remarks, that this shadow, to be distinguished, "must be thrown upon a white ground. An open window in a whitewashed room is the best exposure; in this situation I have observed not only the shadow, but the diffracted fringes edging its outline." The *density* of Venus compared with that of the sun is as 1 to 383,137, according to La Place's calculations, while that of the earth is as 1 to 329,630; so that the earth is somewhat denser than Venus. A body weighing one pound on the earth will weigh only 15 oz. 10 dr. on the surface of Venus. The *eccentricity* of the orbit of Venus is less than that of any of the other planets; it amounts to 492,000 miles, which is only the 1-276 part of the diameter of its orbit, which, consequently, approaches very nearly to a circle. The inclination of its orbit to the ecliptic is 3° 23′ 33″. Its mean apparent diameter is 17″, and its greatest about 57⅓″. Its greatest elongation from the sun varies from 45° to 47° 12′. Its mean arc of *retrogradation*, or when it moves from east to west contrary to the order of the signs, is 16° 12′, and its mean duration forty-two days, commencing or ending when it is about 28° 48′ distant from the sun. Such is a condensed view of most of the facts in relation to Venus which may be considered as interesting to the general reader.

III. OF THE EARTH, CONSIDERED AS A PLANET.

In exhibiting the scenery of the heavens, it is not perhaps absolutely necessary to enter into any particular description of the earth; but as it is the only planetary body with which we are intimately acquainted, and the only standard by which we can form a judgment of the other planetary globes,

and as it is connected with them in the same system, it may be expedient to state a few facts in relation to its figure, motion, structure, and general arrangements.

The earth, though apparently a quiescent body in the centre of the heavens, is suspended in empty space, surrounded on all sides by the celestial luminaries and the spaces of the firmament. Though it appears to our view to occupy a space larger than all the heavenly orbs, yet it is, in fact, almost infinitely smaller, and holds a rank only with the smaller bodies of the universe; and, although it appears to the eye of sense immovably fixed in the same position, yet it is, in reality, flying through the ethereal spaces at the rate of more than a thousand miles every minute, as we have already demonstrated. The *figure* of the earth is now ascertained to be that of an oblate *spheroid*, very nearly approaching to the figure of a globe. An orange and a common turnip are oblate spheroids, and are frequently exhibited to illustrate the figure of the earth. But they tend to convey an erroneous idea; for, although a spheroid of ten feet diameter were constructed to exhibit the true figure of the earth, no eye could distinguish the difference between such a spheroid and a perfect globe, since the difference of its two diameters would scarcely exceed one third of an inch; whereas, if its diameters bore the same proportion to each other as the two diameters of an orange generally do, its polar diameter would be nearly one foot three inches shorter than its equatorial.

Before the time of Newton it was never suspected that the figure of the earth differed in any degree from that of a perfect sphere, excepting the small inequalities produced by the mountains and vales. The first circumstance which led to the determination of its true figure was an accidental experiment made with a pendulum near the equator. M. Richer, a Frenchman, in a voyage made to Cayenne, which lies near the equator, found that the pendulum of his clock no longer made its vibrations so frequently as in the latitude of Paris, and that it was absolutely necessary to shorten it in order to make it agree with the times of the stars passing the meridian. Some years after this, Messrs. Deshayes and Varin, who were sent by the French king to make certain astronomical observations near the equator, found that the pendulum at Cayenne made 148 vibrations less in a day than at Paris, and that his clock was retarded by that means two minutes twenty-eight

seconds; and was obliged to make his pendulum shorter by two lines, or the sixth part of a Paris inch, in order to make the time agree with that deduced from celestial observations. Similar experiments, attended with the same results, were made at Martinique, St. Domingo, St. Helena, Goree, on the coast of Africa, and various other places, in all which it was found that the alteration was the greatest under the equator, and that it diminished as the observer approached the northern latitudes. This discovery, trifling as it may at first sight appear, opened a new field of investigation to philosophic minds; and there are, perhaps, few facts throughout the range of science from which so many curious and important facts have been deduced. Sir Isaac Newton and M. Huygens were among the first who perceived the extensive application of this discovery, and the important results to which it might lead. Newton, whose penetrating eye traced the fact through all its bearings and remote consequences, at once perceived that the earth must have some other figure than what was commonly supposed, and demonstrated that this diminution of weight naturally arises from the earth's rotation round its axis, which, according to the laws of circular motion, repels all heavy bodies from the axis of motion; so that, this motion being swifter at the equator than in other parts more remote, the weight of bodies must also be less there than near the poles. All heavy bodies, when left to themselves, fall towards the earth in lines perpendicular to the horizon; and, were those lines continued, they would all pass through the earth's centre. Every part of the earth, therefore, gravitates towards the centre; and as this force is found to be about 289 times greater than that which arises from the rotation of the earth, a certain balance will constantly be maintained between them, and the earth will assume such a figure as would naturally result from the difference of these two opposite forces. From various considerations and circumstances of this kind, Newton founded his sublime calculations on this subject; and, as Fontenelle remarks, "determined the true figure of the earth without leaving his elbow-chair."

Newton and Huygens were both engaged in these investigations at the same time, unknown to each other, but the results of their calculations were nearly alike. They demonstrated, from the known laws of gravitation, that the true figure of the earth was that of an oblate spheroid, flattened at the

poles, and protuberant at the equator; that the proportion between its polar and equatorial diameters is as 229 to 230, and, consequently, that the polar diameter is shorter than the equatorial by about thirty-four miles.* If these deductions be nearly correct, it follows that a degree of latitude in the polar regions must measure more than a degree near the equator To determine this point by actual measurement, it was ordered by the French king that a degree should be measured both at the equator and within the polar circle. Messrs. Maupertuis, Clairaut, and others were sent to the north of Europe, and Messrs. Bouger, Godin, and La Condamine to Peru, in South America. The first of these companies began their operations at Tornea, near the Gulf of Bothnia, in July, 1736, and finished them in June, 1737. Those who were sent to Peru, having greater difficulties to encounter, did not finish their survey till the year 1741. The results of these measurements were, that a degree of the meridian in Lapland contains 344,627 French feet, and a degree of the meridian at the equator 340,606; so that a degree in Lapland is 4021 French feet, or 4280 English feet, longer than a degree at the equator; that is, they differ about six and a half English furlongs, or 8-10 of a mile. But if the earth had been a perfect sphere, a degree of the meridian in every latitude would have been found precisely of the same length. This spheroidal figure is not peculiar to the earth; for the planets Saturn, Jupiter, and Mars are likewise found to be spheroids, and some of them much flatter at the poles than the earth. The difference between the polar and equatorial diameters of Jupiter is more than 6000 miles.

From the circumstances stated above, we may learn that the most minute facts connected with the system of nature ought to be carefully observed, investigated, and recorded, as they may lead to important conclusions, which, at first view, we may be unable to trace or to appreciate; for in the system of the material world, the greatest and most sublime effects are sometimes produced from apparently simple and even trivial causes. Who could have imagined that such a simple circumstance as the retardation of clocks in southern climes,

* From a comparison of the length of different degrees of the meridian, lately measured, it is probable that the difference of the diameters is somewhat less than is here stated. Its equatorial diameter is about 7934 miles, and its polar about 7908.

and the shortening or lengthening of a pendulum, would lead to such an important discovery as the spheroidal figure of the earth? Hence we may conclude, that if ten thousands of rational observers of the facts of nature were to be added to those who now exist, many parts of the scenery of the universe which are now involved in darkness and mystery might ere long be unfolded to our view.

General Aspect of the Earth's Surface.—The most prominent and distinguishing feature of the surface of our globe is the two bands of *land* and of *water* into which it is divided. These bands present a somewhat irregular appearance and form, but their greatest length is from north to south. One of these bands of land, generally denominated the *eastern* continent, comprehends Europe, Africa, and Asia, and extends from the Cape of Good Hope on the south to the north-eastern extremity of Kamtschatka, in which direction its length measures about 10,000 miles. Its greatest breadth from Corea, or the eastern parts of Chinese Tartary, to the western extremity of Africa, is about 9000 miles. The other band of earth is the *western* continent, comprehending North and South America, lying between the Atlantic on the east and the Pacific ocean on the west. Its greatest length is about 8000 miles from north to south, and its greatest breadth, from Nootka Sound to Newfoundland, North America, and from Cape Blanco to St. Roque, South America, is about 3000 miles. Besides these two larger bands of land, there is the large island of New-Holland, which is 2600 miles long and 2000 broad, which might be reckoned a third continent; along with many thousands of islands, of every form and size, which are scattered throughout the different seas and oceans. The whole of these solid parts of our globe comprehends an area of about forty-nine millions of square miles, or about one fourth of the superficies of the terraqueous globe, which contains about one hundred and ninety-seven millions of square miles. Were all these portions of the land peopled with inhabitants in the same proportion as in England, the population of the globe would amount to thirteen thousand seven hundred and twenty millions of human beings, which is more than *seventeen* times its present number of inhabitants. Yet, strange to tell, this world has, in all ages, been the scene of wars, bloodshed, and contests for small patches of territory, although the one seventeenth part of it is not yet inhabited!

There is a striking correspondence between two sides of the two continents to which we have adverted, the prominent parts of the one corresponding to the indentings of the other. If we look at a terrestrial globe or map of the world, we shall perceive that the projection of the eastern coast of Africa nearly corresponds with the opening between North and South America, opposite to the Gulf of Mexico; that the projection in South America, about Cape St. Roque and St. Salvador, nearly corresponds with the opening in the Gulf of Guinea; so that, if we could conceive the two continents brought into contact, the openings to which I have referred would be nearly filled up, so as to form one compact continent. The Gulf of Guinea would be nearly blocked with the eastern projection of South America, and a large gulf formed between Brazil and the land to the eastward of the Cape of Good Hope. The Gulf of Mexico would be formed into a kind of inland lake, and Nova Scotia and Newfoundland would block up a portion of the Bay of Biscay and the English Channel, while Great Britain and Ireland would block up the entrance to Davis's Straits. A consideration of these circumstances renders it not altogether improbable that these continents were originally conjoined, and that, at some former physical revolution or catastrophe, they may have been rent asunder by some tremendous power, when the waters of the ocean rushed in between them, and left them separated as we now behold them. That POWER which is said to "remove mountains," which "shaketh the earth out of her place," and causeth "the pillars thereof to tremble," is adequate to produce such an effect; and effects equally stupendous appear to have been produced when the waters of the great deep covered the tops of the highest mountains, when the solid strata of the earth were bent and disrupted, and rocks of enormous size transported from one region of the earth to another. There appears no great improbability in the supposition that such an event may have taken place at the universal deluge, when the original constitution of the globe seems to have undergone a dreadful change and disarrangement.

Between the two continents now mentioned are two immense bands of water, extending nearly from the northern to the southern extremities of the globe, one of which is 10,000, and the other 3000 miles broad. These vast collections of water surround the continents and islands, and form numerous

seas, straits, gulfs, and bays, which indent and diversify the coasts through every region of the earth. They occupy a square surface of 148,000,000 of miles, forming about three fourths of the surface of the globe, and containing about 296,000,000 of *cubical* miles of water, sufficient to cover the whole globe to the depth of 2600 yards. This vast superabundance of water, compared with the quantity of land, it is probable, is peculiar to our globe, and that no such arrangement exists on the surface of the other planets of our system. It is probable that such an extensive ocean did not exist at the period of the original formation of the earth, and that such a disproportionate accumulation of water took place in consequence of the deluge. The present constitution of the earth, and the disproportion of the water to the dry land, are circumstances more adapted to a race of fallen intelligences than to beings in a state of innocence, and adorned with the image of their Creator.

Besides the circumstances now stated, the earth is diversified with extensive ranges of mountains, which stretch in different directions along the continents and islands, rearing their summits, in some instances, several miles above the level of the ocean, and diversifying in various modes the landscape of the earth. From these mountains flow hundreds of majestic rivers, some of them more than 2000 miles in length, fertilizing the countries through which they flow, and forming a medium of communication between the inland countries and the ocean The atmosphere is thrown around the whole of this terraqueous mass, by means of which, and the operation of the solar heat, a portion of the ocean is carried up to the region of the clouds in the form of vapour, which diffuses itself over every region of the earth, and is again condensed into rains and dews. to supply the sources of the rivers, and to distribute fertility throughout every land. This atmosphere is the region of the *winds*, whether fanning the earth with gentle breezes, or heaving the ocean into mountainous billows, and overturning forests by hurricanes and tornadoes. It is the theatre where thunders roll and lightnings flash, where the fiery meteor sweeps along with its luminous train, and where the *auroræ boreales* display their fantastic coruscations. It is constituted by a law of the Creator to sustain the principle of life, and to preserve in existence and in comfort not only man, but all the tribes of animated existence which traverse the regions of

earth, air, or sea, without the benign influence of which this globe would be soon left without a living inhabitant.

Were the earth to be viewed from a point in the heavens, suppose from the moon, it would present a pretty variegated, and sometimes a mottled appearance. The distinction between its seas, oceans, continents, and islands would be clearly marked, which would appear like brighter and darker spots upon its disk. The continents would appear bright, and the ocean of a darker hue, because water absorbs the greater part of the solar light that falls upon it. The level plains (excepting, perhaps, such spots as the Arabian deserts of sands) would appear of a somewhat darker colour than the more elevated and mountainous regions, as we find to be the case on the surface of the moon. The islands would appear like small bright specks on the darker surface of the ocean; and the lakes and Mediterranean seas like darker spots, or broad streaks intersecting the brighter parts or the land. By its revolution round its axis, successive portions of its surface would be brought into view, and present a different aspect from the parts which preceded. Were the first view taken when the middle of the Pacific Ocean appeared in the centre, almost the whole hemisphere of the earth would present a dull and sombre aspect, except a few small spots near the middle, where the Marquesas, the Sandwich, and the Society Isles are situated, and some bright streaks on its northeastern, northwestern, and southwestern borders, where the northwestern parts of America, the northeastern parts of Asia and New Holland are situated. In about six hours afterward the whole of Asia, with its large islands, Borneo, Sumatra, New Guinea, &c., would come into view and diversify the scene, having a portion of the Pacific on the east, and the Indian Ocean and a portion of Africa on the west. In another six hours the whole of Africa and Europe, the Atlantic Ocean, and the eastern part of South America, would make their appearance; and in six hours more the whole of North and South America would appear near the centre of the view, having the Atlantic Ocean on the east and the Pacific on the west. All these views would present a considerable variety of aspect, but in every one of them the darker shades would appear to cover the greater part of the view, except, perhaps, in that view which takes in the whole of Asia and part of Africa and Europe. Each of these views occasionally pre-

sent a mottled and unstable appearance, on account of the numerous strata of clouds suspended over different regions, which would be seen frequently to shift their positions. These clouds, when dense, and accumulated over particular countries, would prevent certain portions of the land and water from being distinctly perceived, They would sometimes appear like bright spots upon the ocean, by the reflection of the solar rays from their upper surfaces, and sometimes like dark spots over the land. The following figures represent two of the views to which we have alluded :—

Fig. XXV. Fig. XXVI.

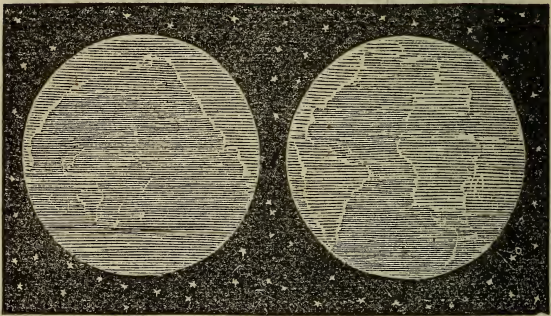


Fig. XXV. represents the appearance of the earth when the middle of the Pacific is in the centre of the view. Fig. XXVI. is the appearance when the Atlantic is presented to the spectator's eye, with South and part of North America on the west, and Europe, Africa, and a portion of Asia on the east.

Internal Structure of the Earth.—We are now pretty well acquainted with the general outline of the surface of the earth, and the different ramifications of land and water with which it is diversified, except those regions which lie adjacent to the poles. But our knowledge of its *internal* structure is extremely limited. The deepest mines that have ever been excavated do not descend above a mile from the surface, and this depth is no more, compared with the thickness of the

earth, than the slight scratch of a pin upon a large artificial globe compared with the extent of its semidiameter. What species of materials are to be found two or three thousand miles within its surface, or even within fifty miles, will, perhaps, be for ever beyond the power of mortals to determine. Various researches, however, have been lately made as to the materials which compose its upper strata, immediately beneath the surface, and the order in which they are arranged. From these researches we learn that substances of various kinds compose the exterior crust of the globe, and that they are thrown together in almost every possible position; some horizontal, some vertical, and some inclined to each other at various angles. Geologists have arranged the strata of the crust of the earth into various classes: 1. *Primary* rocks, which are supposed to have been formed before all the others, and which compose, as it were, the great frame or groundwork of our globe. These rocks are composed of *granite*, *gneis*, *mica-slate*, and other substances; they form the most lofty mountains, and, at the same time, extend themselves downward beneath all the other formations, as if all the materials on the surface of the globe rested upon them as a basis. 2. *Transition* rocks, which are above the primitive, and rest upon them, and are composed of the larger fragments of the primary rocks, consolidated into continuous masses. These rocks contain the remains of certain organized beings, such as seashells, while no such remains are found among the rocks termed primitive. 3. *Secondary* rocks, which lie upon the primary and transition rocks, and which appear like deposites from the other species of rocks. The substances which this class of rocks contain are secondary limestone, coal, oolite, sandstone, and chalk. There are likewise *tertiary*, *basaltic*, and *volcanic* rocks, and *alluvial* and *diluvial* deposites. But it would be foreign to our present subject to descend into particulars.

From facts which have been ascertained respecting these and various other circumstances connected with the constitution of the earth, it has been concluded that important changes and astonishing revolutions have taken place in its physical structure since the period of its formation; that rocks of a huge size have been rolled from one region of the globe to another, and been carried up even to the tops of hills and elevated portions of the land; that the hardest masses of its

rocks have been fractured, and its strata bent and dislocated; that in certain places seashells, sharks' teeth, the bones of elephants, the hippopotamus, oxen, deer, and other animals, are found mingled together, as if they had been swept along by some overpowering force, amid a general convulsion of nature; that the bed of the ocean has been raised up, by the operation of some tremendous power, so as to form a portion of the habitable surface of the globe; and that the loftiest mountains were once covered by the waters of the ocean. From these and other considerations we have reason to believe that the earth now presents a very different aspect from what it did when it first proceeded from the creating hand of its Maker, and when all things were pronounced by him to be "very good." The earth, therefore, as presently constituted, ought not to be considered as a standard or model to be compared with the other planets of our system, and by which to judge whether they appear to be fitted for being the abodes of intelligent beings. For, in its present state, notwithstanding the numerous objects of sublimity and beauty strewed over its surface, it can be considered as little more than a majestic ruin; a ruin, however, sufficiently accommodated to the character of the majority of inhabitants who have hitherto occupied its surface, whose conduct, in all ages, has been marked with injustice, devastation, and bloodshed.

Density of the earth.—In the year 1773, Dr. Maskeline, the astronomer royal, with other gentlemen, made a number of observations on the mountain Schehallien, in Scotland, to determine the *attraction of mountains*. After four months spent in the necessary arrangements and observations, it was ascertained beyond dispute that the mountain exerted a *sensible* attraction, leaving no hesitation as to the conclusion that every mountain and every particle of earth is endowed with the same property in proportion to its quantity of matter. The observations were made on both sides of the mountain, and from these it appears that the sum of the two contrary attractions exerted upon the plumbline of the instruments was equal to eleven seconds and a half. Professor Playfair, more than thirty years afterward, from personal observation, endeavoured to determine the specific gravity or density of the materials of which Schehallien is composed, and, after numerous experiments and calculations, it was concluded that "the mean density of the earth is nearly double the density of the rocks which

compose that mountain," which seem to be considerably more dense than the mean of those which form the exterior crust of the earth. The density of these rocks was reckoned to be two and a half times the weight of water; consequently the density of the earth is to that of water as five to one; that is the whole earth, bulk for bulk, is *five times the weight of water*, so that the earth, as now constituted, would counterpoise five globes of the same size composed of the same specific gravity as water. As the mean density, therefore, of the whole earth's surface, including the ocean, cannot be above twice the density of water, it follows that the *interior* of the earth must have a much greater density than even five times the weight of water, to counterbalance the want of weight on its surface. Hence we are necessarily led to conclude that the interior parts of the earth, near the centre, must consist of very dense substances, denser than even iron, lead, or silver, and that no great internal cavity can exist within it, as some theorists have supposed, unless we could suppose that most of the materials far below the foundations of the ocean are much denser than the heaviest metallic substances yet discovered. La Place has attempted to estimate the earth's density near the centre on the following data: If 5 2-5 be its mean density, and 3 1-8, 3 1-5, 2 4-5, and 2 3-5 be assumed as its superficial densities, then, on the theory of compressibility, the density at the centre will be $13\frac{1}{4}$, $14\frac{1}{2}$, $15\frac{3}{4}$, and 20 1-10 respectively. The least of the specific gravities ($13\frac{1}{4}$) is nearly double the density of zinc, iron, and the ore of lead; and the greatest (20 1-10) is nearly equal to purified and forged *platina*, which is the most ponderous substance hitherto discovered. Yet this ponderous globe, with all the materials on its surface, is carried through the regions of space with a velocity of sixteen hundred thousand miles every day.

Variety of Seasons.—The annual revolution of the earth is accomplished in 365 days, 5 hours, 48 minutes, and 51 seconds. In the course of this revolution, the inhabitants of every clime experience, though at different times, a variety of seasons. Spring, summer, autumn, and winter follow each other in constant succession, diversifying the scenery of nature, and distinguishing the different periods of the year. In those countries which lie in the southern hemisphere of the globe, November, December, and January are the summer months, while in the northern hemisphere, where we reside,

these are our months of winter, when the weather is coldest and the days are shortest. In the northern and southern hemispheres the seasons are opposite to each other, so that when it is spring in the one it is autumn in the other; when it is winter in southern latitudes it is summer with us. During six months, from March 21 to September 23, the sun shines without intermission on the north pole, so that there is no night there during all that interval, while the south pole is all this time enveloped in darkness. From September to March the south pole enjoys the solar light, while the north, in its turn, is deprived of the sun and left in darkness. The sun is at different distances from the earth at different periods of the year, owing to the earth's moving in an elliptical orbit; but it is not upon this circumstance that the seasons depend. For on the first of January we are more than three millions of miles nearer the sun than on the first of July, when the heat of our summer is generally greatest. The true cause of the variation of the seasons consists in the inclination of the axis of the earth to the plane of its orbit; or, in other words, to the *ecliptic*. If its axis were *perpendicular* to the ecliptic, the equator and the orbit would coincide; and as the sun is always in the plane of the ecliptic, it would in this case be always over the equator; the two poles would be always enlightened, and there would be no diversity of days and nights, and but one season throughout the year. What is meant by the inclination of the axis will appear from the following figures. (See *Figures* XXVII. and XXVIII.)

Let A B represent the plane of the ecliptic, or the earth's orbit, and C D (Fig. XXVIII.) the axis of the earth, inclined at an angle of 66½° to the ecliptic, and 23½° from the perpendicular E F, or the axis of the ecliptic, and it will represent the position of the axis of the earth with respect to the plane of its orbit. Fig. XXVII. represents the axis of the earth, G H, *perpendicular* to the ecliptic. As the sun can enlighten only the one half of the globe at a time, it is evident that, if his rays come in the direction from B, Fig. XXVIII., they cannot illuminate both poles at once. While the north polar circle between E and C is enlightened, the regions around the south pole between D and F must necessarily remain in the dark. But if the axis of the earth were perpendicular to its orbit, as exhibited in Fig. XXVII., then both poles would constantly be enlightened at the same time. The

Fig. XXVII.

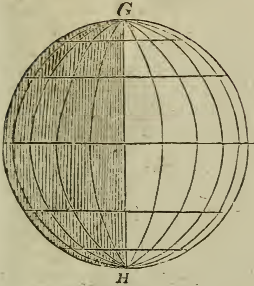
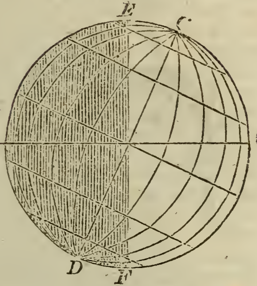


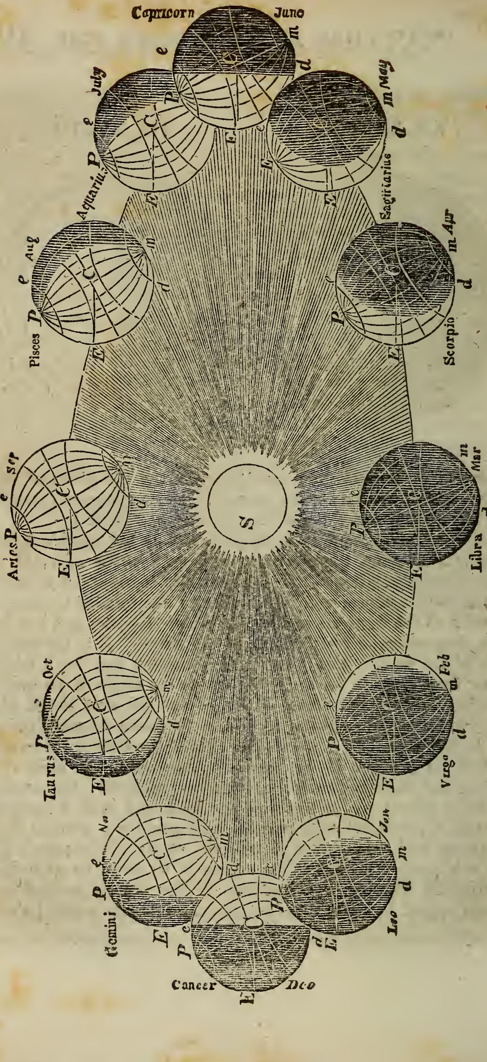
Fig. XXVIII.



following figure will more particularly show the effect of the inclination of the axis of the earth during its progress through the twelve signs of the zodiac. (See *Fig.* XXIX.)

In this representation the ellipse exhibits the earth's orbit seen at a distance, the eye being supposed to be elevated a little above the plane of it. The earth is represented in each of the twelve signs, with the names of the months annexed. In each of the figures *e* is the pole of the ecliptic, and *e d* its axis, perpendicular to the plane of the orbit. *P* is the north pole of the earth; *P m* its axis, about which the earth daily turns from west to east; *P C e* shows the angle of its inclination. During the whole of its course the axis keeps always in a parallel position, or points always to the same parts of the heavens. If it were otherwise, if the axis of the earth shifted its position in any considerable degree, the most appalling and disastrous effects might be produced; the ocean in many places might overflow the land, and rush from the equator towards the polar regions, and produce a general devastation and destruction to myriads of its inhabitants. If the axis pointed always to the centre of its orbit, so as to be continually varying its direction, all the objects around us would appear to whirl about in confusion; there would be no

Fig. XXIX.



Capricorn
June
July
May
Aquarius
Sagittarius
Aug
Apr
Pisces
Scorpio
Sep
Mar
Aries
S
Libra
Oct
Feb
Taurus
Virgo
Nov
Jan
Gemini
Leo
Cancer
Dec

fixed polar points to guide the mariner, nor could his course be directed through the ocean by any of the stars of heaven.

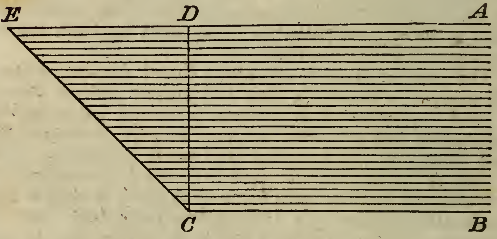
When the earth is in the first point of Libra, the sun appears in the opposite point of the ecliptic, at Aries, about the 21st of March; and when the earth is in Aries, the sun, *S*, will appear in Libra about the 23d of September. At these times both poles of the earth are enlightened, and the day and night are equal in all places. When the earth has moved from Libra to Capricorn, its axis keeping always the same direction, all places within the north polar circle, *P e*, are illuminated throughout the whole diurnal revolution, at which time the inhabitants of those places have the sun more than twenty-four hours above the horizon. This happens at the time of our summer solstice, or about the 21st of June, at which time the south polar circle, *d m*, is in darkness. While the earth is moving from Libra, through Capricorn, to Aries, the north pole, *P*, being in the illuminated hemisphere, will have six months continual day; but while the earth passes from Aries, through Cancer, to Libra, the north pole will be in darkness, and have continual night; the south pole at the same time enjoying continual day. When the earth is at Cancer, the sun appears at Capricorn, at which season the nights in the northern hemisphere will as much exceed the days as the days exceeded the nights when the earth was in the opposite point of its orbit.

Our summer is nearly eight days longer than our winter. By summer is meant the time that passes between March 21 and September 23, or between the vernal and autumnal equinoxes; and by winter, the time between September 23 and March 21, the autumnal and vernal equinoxes. The portion of the earth's orbit which lies north of the equinoctial contains 184 degrees, while that portion which is south of the equinoctial contains only 176 degrees, being eight degrees less than the other portion, which is the reason why the sun is nearly eight days longer on the north of the equator than on the south. In our summer the sun's apparent motion is through the six northern signs, Aries, Taurus, Gemini, Cancer, Leo, and Virgo; and in our winter, through the six southern. In the former case, from March 21 to September 23, the sun is about 186 days 11 hours in passing through the northern signs, and only 178 days 18 hours in passing through the southern signs, from September 23 to March

21, the difference being about 7 days 17 hours. The reason of this difference is, that the earth moves in an elliptical orbit, one portion of which is nearer the sun than another, in consequence of which the sun's apparent motion is slower while it appears in the northern signs than while it traverses the southern ones.

As the sun is farther from us in summer than in winter, it may naturally be asked why we experience the greatest heats in the former season. The following, among other reasons, may be assigned, which will partly account for this effect: 1. The sun rises to a much higher altitude above the horizon in summer than in winter, and, consequently, its rays falling more directly and less oblique, the thicker or denser will they be, and so much the hotter, when no counteracting causes *from local circumstances* exist. Thus, supposing a parcel of rays, *A B C D E* (Fig. XXX.) to fall perpendicularly on any plane (*D C*), and *obliquely* on another plane (*E C*), it is evident they will occupy a smaller space (*D C*) in the former than (*E C*) in the latter; and, consequently, their

Fig. XXX.



heat would be much greater in the lesser space *D C* than in the larger space *E C*. If, instead of lines, we suppose *D C* and *E C* to be the diameters of surfaces, then the heat on those surfaces will be inversely as the squares of the diameters. Let *D C* be 20 and *E C* 28; the square of 20 is 400, and the square of 28 is 784, which is nearly double the square of *D C*, and, consequently, there is nearly double the quantity

of heat on $D\ C$ compared with that on $E\ C$, in so far as it depends on the *direct* influence of the solar rays; but other causes may concur either to diminish or increase the heat in certain places, to which I have already alluded when describing the phenomena of Mercury. 2. The greater length of the day contributes to augment the heat in summer; for the earth and the air are heated by the sun in the daytime more than they are cooled in the night, and on this account the heat will go on increasing in the summer, and for the same reason will decrease in winter, when the nights are longer than the days. 3. Another reason is, that in summer, when the sun rises to a great altitude, his rays pass through a much smaller portion of the atmosphere, and are less refracted and weakened by it than when they fall more obliquely on the earth, and pass through the dense vapours near the horizon.

The cause of the variety of the seasons can be exhibited with more clearness and precision by means of machinery than by verbal descriptions; and, therefore, those whose conceptions are not clear and well defined on this subject should have recourse to orreries and planetariums, which exhibit the celestial motions by wheelwork. There is a small instrument, called a *Tellurian*, which has been long manufactured by Messrs. Jones, Holborn, London, which conveys a pretty clear idea of the motions and phases of the moon, the inclination of the earth's axis to the plane of its orbit, and the changes of the seasons. It may be procured at different prices, from 1*l*. 8*s*. to 4*l*. 14*s*. 6*d*., according to the size and the quantity of the wheelwork.

The subject of the seasons and the variety of phenomena they exhibit have frequently been the themes both of the philosopher and the poet, who have expatiated on the beauty of the contrivance and the benignant effects they produce; and therefore they conclude that other planets enjoy the same vicissitudes and seasons similar or analogous to ours. But although, *in the present constitution of our globe*, there are many benign agencies which accompany the revolutions of the seasons, and are essential to our happiness in the circumstances in which we now exist, yet it is by no means probable that the seasons, *as they now operate*, formed a part of the original arrangements of our terrestrial system. Man was at first created in a state of innocence, and adorned with the image of his Maker; and the frame of nature, we may confidently

suppose, was so arranged as to contribute in every respect both to his sensitive and intellectual enjoyment. But neither the horrors of winter, and its dreary aspect in northern climes, nor the scorching heats and appalling thunderstorms which are experienced in tropical climates, are congenial to the rank and circumstances of beings untainted with sin and endowed with moral perfection. Such physical evils and inconveniences as the change of seasons occasionally produces appear to be only adapted to man in his present state of moral degradation. In the primeval state of the world it is not unlikely that the axis of the earth had a different direction from what it has at present, and that, instead of scorching heats and piercing colds, and the gloom and desolations of winter, there was a more mild and equable temperature, and something approaching to what the poets call "a perpetual spring." We are assured, from the records of sacred history, that the original constitution of the earth has undergone a considerable change and derangement: its strata were disrupted, "the fountains of the great deep were broken up," and a flood of waters covered the tops of the loftiest mountains; the effects of which are still visible in almost every region of the globe. At that memorable era, it is highly probable, those changes were introduced which diversify the seasons and produce those alarming phenomena and destructive effects which we now behold; but as man advances in his moral, intellectual, and religious career, and in proportion as his mental and moral energies are made to bear on the renovation of the world, he has it in his power to counteract or meliorate many of the physical evils which now exist. Were the habitable parts of the earth universally cultivated, its marshes drained, and its desolate wastes reduced to order and vegetable beauty by the hand of art, and replenished with an industrious and enlightened population, there can be little doubt that the seasons would be considerably meliorated, and many physical evils prevented with which we are now annoyed. And all this is within the power of man to accomplish, provided he chooses to direct his wealth, and his intellectual and moral energies, into this channel. If these remarks have any foundation in truth, then we ought not to imagine that the earth is a standard by which we are to judge of the state of other planetary worlds, or that they are generally to be viewed as having a diversity of seasons similar to ours

The following facts, in addition to the preceding, may be noted in relation to the earth: Under the equator, a pendulum, of a certain form and length, makes 86,400 vibrations in a mean solar day; but, when transported to London, the same pendulum makes 86,535 vibrations in the same time. Hence it is concluded that the intensity of the force urging the pendulum downward at the equator is to that at London as 86,400 to 86,535, or as 1 to 1·00315; or, in other words, that a mass of matter at the equator weighing 10,000 pounds, exerts the same pressure on the ground as 10,031½ of the *same pounds* transported to London would exert there. If the gravity of a body at the equator be 1, at the poles it will be 1·00569, or about the 1-194 part heavier; that is, a body weighing 194 pounds at the equator would weigh 195 pounds at the north pole; so that the weight of bodies is increased as we advance from the equator to the poles, owing to the polar parts being nearer the centre of the earth than the equatorial, and the centrifugal force being diminished. It is this variation of the action of gravity in different latitudes that causes the same pendulum to vibrate slower at the equator than in other places, as stated above. For a pendulum to oscillate seconds at the equator, it must be thirty-nine inches in length; and at the poles, thirty-nine and one fifth inches.

The *tropical* year, or the time which the sun (or the earth) takes in moving through the twelve signs of the ecliptic, from one equinox to the same equinox again, is three hundred and sixty-five days, five hours, forty-eight minutes, and fifty-one seconds. This is the proper or natural year; because it always keeps the same seasons to the same months. The *sidereal* year is the space of time the sun takes in passing from any fixed star till it returns to the same star again. It consists of three hundred and sixty-five days, six hours, nine minutes, and eleven and a half seconds, being twenty minutes and twenty and a half seconds longer than the true solar year. This difference is owing to the regression of the equinoctial points, which is fifty seconds of a degree every year; and, to pass over this space, the sun requires twenty minutes and twenty and a half seconds. The earth moves in an elliptical orbit, whose *eccentricity*, or distance of its foci from the centre, is 1,618,000 miles: that is, the ellipse or oval in which it moves is double the eccentricity, or 3,236,000 miles longer in one direction than it is in another, which is the reason

that the sun is farther from us at one season of the year than at another. This is ascertained from the variation of the apparent diameter of the sun. About the 1st of January, when he is nearest the earth, the apparent diameter is thirty-two minutes, thirty-five seconds; and on the 1st of July, when he is most distant, it is only thirty-one minutes, thirty-one seconds. This proves that the earth has a slower motion in one part of its orbit than in another. In January it moves at the rate of about 69,600 miles an hour, but in July its rate of motion every hour is only about 66,400 miles; a difference of more than 3000 miles an hour.

IV. OF THE PLANET MARS.

The earth is placed, in the solar system, in a position between the orbits of Venus and Mars. The two planets, Mercury and Venus, which are placed *within* the orbit of the earth, and whose orbits lie between it and the sun, are termed the *inferior* planets. Those whose orbits lie *beyond* the orbit of the earth, at a greater distance from the sun, as Mars, Jupiter, Saturn, and Uranus, are termed *superior* planets. The motions and aspects of all the superior planets, as seen from the earth, differ considerably from those which are exhibited by the inferior. In the first place, the inferior planets are never seen but in the neighbourhood of the sun, none of them ever appearing beyond forty-eight degrees from that luminary; whereas the superior planets appear at all distances from the sun, even in the opposite quarter of the heavens, or 180 degrees from the point in which the sun may happen to be placed. This could not possibly happen unless their orbits were *exterior* to that of the earth, and the earth placed at such times between them and the sun. In the next place, the inferior planets, when viewed through telescopes, exhibit, at different times, all the phases of the moon; but the superior planets never appear either horned or in the shape of a half moon. The planets Jupiter, Saturn, and Uranus never appear in any other shape than *round*, or with full enlightened hemispheres. This circumstance of itself furnishes a proof that we see these planets always in a direction not very remote from that in which they are illuminated by the solar rays; and, consequently, that we occupy a station which is never very far removed from the centre of their orbits. It proves, in other words, that the path of the earth round the sun is en-

tirely included within their orbits, and likewise that this circular path of the earth *is of small diameter compared with their more expansive orbits.* This may be illustrated by the following figures. Let *S*, Fig. XXXII., represent the sun; *A B* the orbit of the earth; and *C* the planet Saturn, about ten times farther from the sun than the earth is. Suppose *B* to represent the earth at its greatest elongation from the sun, as seen from Saturn; the angle, *S C B*, being so small, it is evident that an observer on the earth, at *B*, can

Fig. XXXI.

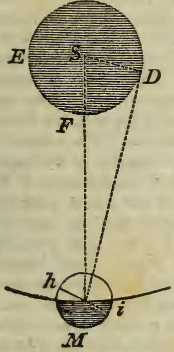


Fig. XXXII.

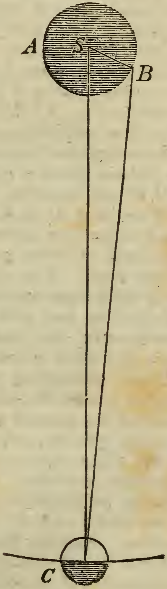


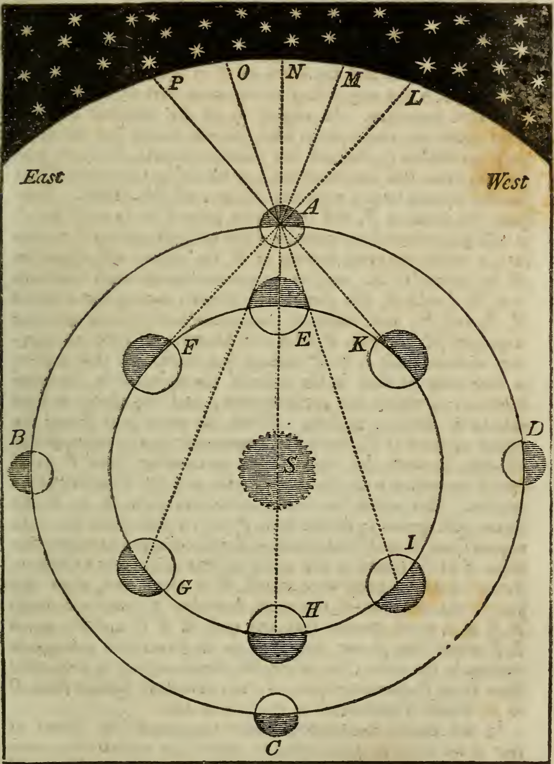
FIG. 33.

see little or nothing of the dark hemisphere of Saturn at *C*, but must perceive the whole enlightened hemisphere of the planet, within a small fraction, which fraction is not perceptible by our best telescopes.

There is only one of the superior planets that exhibits any perceptible *phase*, and that is the planet *Mars*. In Fig. XXXI. *S* represents the sun; *E D* the orbit of the earth; *M* Mars; and *D* the earth at its greatest elongation, as seen from Mars. In this case the angle *S M D* is much larger than in the former case, as Mars is much nearer to the earth than Saturn or any other of the superior planets. Consequently, a spectator on the earth is enabled to see a greater portion of the dark hemisphere of Mars, and, of course, loses sight of a corresponding portion of his enlightened disk. This is represented by the line *h i*. This *gibbous* phase of Mars, however, differs only in a small degree from a circle; it is never less than seven eighths of the whole disk. This phase is represented in Fig. XXXIII. When the earth arrives near the point *F*, when Mars appears in opposition to the sun, the whole of his enlightened hemisphere is then visible. The extent of the gibbous phase of this planet affords a measure of the angle *S M D*, and, therefore, of the proportion of the distance, *S M*, of Mars, to *S D* or *S F*, the distance of the earth from the sun, by which we are warranted to conclude that the *diameter of the orbit* of Mars cannot be less than 1 1-2 that of the orbit of the earth. The phases of Saturn, Jupiter, and Uranus being quite imperceptible, demonstrates that their orbits must include both the orbit of the earth and that of Mars; and, consequently, that they are removed at a much greater distance than either of these bodies from the centre of the system.

Before proceeding to a particular description of the phenomena connected with the planet Mars, I shall give a brief sketch of the *motions* peculiar to this planet, which will serve, in some measure, as a specimen of the apparent motions of all the other superior planets. In the following figure *S* represents the sun; *A B C D* the planet Mars in four different positions in its orbit; *E F G H I K*, the orbit of the earth; and *L M N O P*, a segment of the starry heavens. Suppose Mars at *A* and the earth at *E*, directly between it and the sun, then all the planet's enlightened hemisphere will be turned towards the earth, and it will appear like the full moon. When the planet is at *B* it will be

Fig. XXXIV.



gibbous, like the moon a few days before or after the full. At C it would again appear wholly enlightened, were it not in the

same part of the heavens with the sun. At D it is again gibbous, as seen from E, and will appear less gibbous as it advances towards A. At A it is said to be in *opposition* to the sun, being seen from the earth at E among the stars at N, while the sun is seen in the opposite direction, $E\ C$. When the planet is at C and the earth at E, it is said to be in *conjunction* with the sun, being in the same part of the heavens with that luminary. In regard to all the superior planets, there is but *one* conjunction with the sun during the course of their revolution; whereas the inferior planets, Mercury and Venus, have *two* conjunctions, as formerly explained. Let us now attend to the *apparent motions* of this planet. Suppose the earth at F, and the planet at rest in its orbit at A, it will be projected or seen by a ray of light among the stars at L; when the earth arrives at G, the planet will appear at M, by the ray $G\ M$; and, in the same manner, when the earth is at H, I, and K, the planet will be seen among the stars at N, O, and P; and, therefore, while the earth moves over the large part of its orbit, $F\ H\ K$, the planet will have an apparent motion from L to P among the stars, and this motion is from west to east, in the order of the signs, or in the same direction in which the earth moves; and the planet is then said to be *direct* in motion. When the earth is at K and the planet appears at P, for a short space of time it appears *stationary*, because the ray of light proceeding from P to K nearly coincides with the earth's orbit and the direction of its motion. But when the earth moves on from K to E, the planet will appear to return from P to N; and while the earth moves from E to F, the planet will still continue to retrograde from N to L, where it will again appear stationary as before. From what has been now stated, it is clear that, since the part of the orbit which the earth describes in passing through $F\ H\ K$ is much greater than the arch $K\ E\ F$, and the space $L\ P$ which the planet describes in its direct and retrograde motion is *the same*; therefore, *the direct motion is very slow* from L to P, in comparison of the *retrograde motion* from P to L, which is performed in much less time.

In the above description I have supposed the planet at *rest* in its orbit at A, in order to render the explanation more easy and simple, and the diagram less complex than it would have been had we traced the planet through different parts of its orbit, together with the motions of the earth. But the ap-

pearances are the same, whether we suppose the planet to be at rest or in motion. The only difference is in the *time* when the retrograde or direct motions happen, and in *the places* of the heavens where the planet will be at such times situated. What has now been stated in regard to the apparent motions of Mars will apply to Jupiter, Saturn, and all the superior planets, making allowance for the difference of *time* in which their direct and retrograde motions are performed. All the superior planets are retrograde in their apparent motions when in *opposition*, and for some time before and after; but they differ greatly from each other, both in the extent of their *arc* of retrogradation, in the *duration* of their retrograde movement, and in its *rapidity*, when swiftest. It is more extensive and rapid in the case of Mars than of Jupiter, of Jupiter than of Saturn, and of Saturn than of Uranus. The longer the periodic time or annual revolution of a superior planet, the more frequent are its stations and retrogradations; they are less in quantity, but continue a longer time. The mean arc of retrogradation of Mars, or from P to L, Fig. XXXIV., is sixteen degrees, twelve minutes, and it continues about seventy-three days; while the mean arc of retrogradation of Jupiter is only nine degrees, fifty four minutes, but its mean duration is about 121 days. The time between one opposition of Saturn and another is 378 days, or one year and thirteen days. The time between two conjunctions or oppositions of Jupiter is 398 days, or one year and thirty-three days. But Mars, after an *opposition*, does not come again into the same situation till after two years and fifty days. It is only at and near the time of the opposition of Mars that we have the best telescopic views of that planet, as it is then nearest the earth; and, consequently, when it has passed its opposition for any considerable time, a period of two years must elapse before we see it again in such a conspicuous situation. Hence it is that this planet is seldom noticed by ordinary observers, except during a period of three or four months every two years. At all other times it dwindles to the apparent size of a small star.

Distance, Motion, and Orbit of Mars.—This planet is ascertained to be about 145 millions of miles from the sun. From what we have stated above it is obvious that, in the course of its revolution, it is at very different distances from the earth. When at its greatest distance, as when the earth

is at E, and the planet at C, Fig. XXXIV., it is 240 millions of miles from the earth. This will appear from an inspection of the figure. The distance, $E\ S$, from the earth to the sun is 95 millions of miles; the distance, $S\ C$, of Mars from the sun is 145 millions. These distances added together amount to the whole distance from E to C, or from the earth to Mars when in conjunction with the sun. When nearest the earth, as at A, it is only 50 millions of miles distant from us. For as the whole distance of the planet from the sun, $A\ S$, is 145 millions, subtract the distance of the earth from the sun, $E\ S$ $=95$ millions, and the remainder will be the distance of the planet, $E\ A=50$ millions of miles from the earth. Small as this distance may appear compared with that of some of the other planets, it would require more than 285 years for a steam-carriage, moving without intermission at the rate of twenty miles an hour, to pass over the space which intervenes between the earth and Mars at its nearest distance.

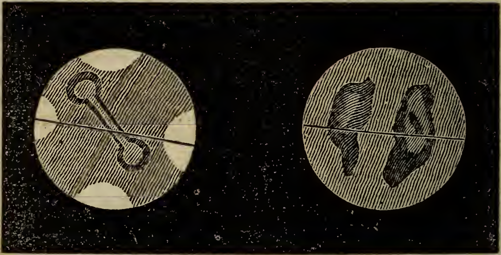
From what has been now stated, it is evident that this planet will present a very different aspect as to size and splendour in different parts of its orbit. When nearest to the earth, it appears with a surface twenty-five times larger than it does at its greatest distance, and seems to vie with Jupiter in apparent magnitude and splendour. But, when verging towards its conjunction with the sun, it is almost imperceptible. And this is one proof, among others, of the truth of the Copernican system. All its motions, stations, and direct and retrograde movements, and the times in which they happen, exactly accord with its position in the system and the motion of the earth, as a planet between the orbits of Venus and Mars. Whereas, were the earth supposed to be the centre of this planet's motion, according to the Ptolemaic hypothesis, it would be impossible to account for any of the phenomena above stated.

The orbit of Mars is 901,064,000, or more than 900 millions of miles in circumference. Through this space it moves in one year and 322 days, or in 16,488 hours. Consequently, its rate of motion is 54,649 miles every hour, which is more than a hundred times the greatest volocity of a cannon ball when it leaves the mouth of the cannon. The diurnal rotation of this planet, or its revolution round its axis, is accomplished in twenty-four hours, thirty-nine minutes, twenty-one seconds, which is about two thirds of an hour longer than our day.

This period of rotation was first ascertained by Cassini, from the motion of certain spots on its surface, which I shall afterward describe. Its axis is inclined to the plain of its orbit in an angle of thirty degrees, eighteen minutes, which is nearly seven degrees more inclined from the perpendicular than that of the earth. This motion is in the same direction as the rotation of the earth, namely, from west to east. The inclination of the orbit of Mars to that of the earth is one degree, fifty-one minutes, six seconds, so that this planet is never so much as two degrees either north or south of the ecliptic. The orbit of Mars is considerably *eccentric*. Its eccentricity is no less than 13,463,000 miles, or about 1-21 of its diameter, which is more than eight times the eccentricy of the orbit of the earth. Hence it follows, that Mars, when in opposition to the sun, may be nearer the earth by a considerable number of millions of miles at one time than at another, when he happens to be about his *perihelion*, or nearest distance from the sun at such opposition. On the 27th of August, 1719, this planet was in such a position, being in opposition within two and a half degrees of its perihelion, and nearer to the earth than it had been for a long period before; so that its magnitude and brightness were so much increased that, by common spectators, it was taken for a new star.

Appearance of the Surface of Mars when viewed through Telescopes.—It was not before the telescope was brought to a certain degree of perfection that spots were discovered on the surface of Mars. This instrument was first directed to the heavens by Galileo, in the year 1610; but it was not till the beginning of 1666 that any of the spots which diversify this planet were discovered. On the 6th of February that ear, in the morning, Cassini, with a telescope of sixteen feet ong, saw two dark spots on the face of Mars, as represented in Fig. XXXV.; and on February 24, in the evening, he saw on the other face of the planet two other spots, somewhat like those of the first, but larger, as represented in Fig. XXXVI. These figures are copied from the first volume of the Transactions of the Royal Society. Afterward, continuing his observations, he found the spots of these two faces to turn by little and little from east to west, and to return at last to the same situation in which he had first seen them. Campani and several other astronomers observed similar spots about the same time at Rome, and Dr. Hook in England.

FIG. XXXV. FIG. XXXVI.



Some of these observers were led to conclude, from the motion of these spots, that the rotation of this planet was accomplished in thirteen hours ; but Cassini, who observed them with particular care, proved that the period of rotation was about twenty-four hours and forty minutes, and showed that the error of the other astronomers arose from their not distinguishing the difference of the spots which appeared on the opposite sides of the disk of Mars. The deductions of Cassini on this point have been fully confirmed by subsequent observations.

Maraldi, a celebrated French mathematician and astronomer, made particular observations on these spots in the year 1704. He observed that the spots were not always well defined, and that they often changed their form, not only in the space of time from one opposition to another, but even within the space of a month ; but some of them continued of the same form long enough to ascertain their periods. Among these was an oblong spot, not unlike one of the broken belts of Jupiter, that did not reach quite round the body of Mars, but had, not far from the middle of it, a small protuberance towards the north, so well defined as to enable him to settle the period of its revolution at twenty-four hours, thirty-nine minutes ; only one minute less than as Cassini had determined it. This appearance of Mars is represented in Fig. XXXVII. On the 27th of August, 1719, the same observer, with a telescope of thirty four feet in length, perceived, among several other

spots, a long belt that reached about half way round the planet, not parallel to its equator, to the end of which another short belt was joined, so as to form an angle a little obtuse, as represented in Fig. XXXVIII.

Fig. XXXVII.

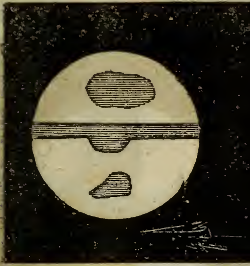
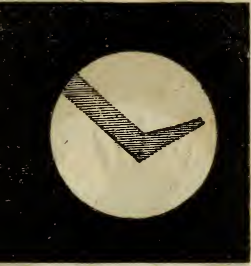


Fig. XXXVIII.



The following figures represent the appearance of the spots as seen by Dr. Hook in 1666. He saw Mars on March 3, 1666, as represented in Fig. XXXIX., which appearance was taken down at the moment of observation. On the 23d of the same month he perceived the spots as delineated in Fig. XL., which appears to have been either the same spots

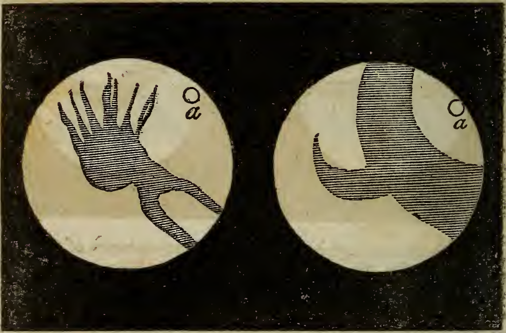
Fig. XXXIX.

Fig. XL.

in another position, or some other spots on the other hemisphere of the planet.

The following are two views of this planet by Sir William Herschel, who has given a great variety of delineations of the different appearances of Mars in the Transactions of the Royal Society of London for 1784.

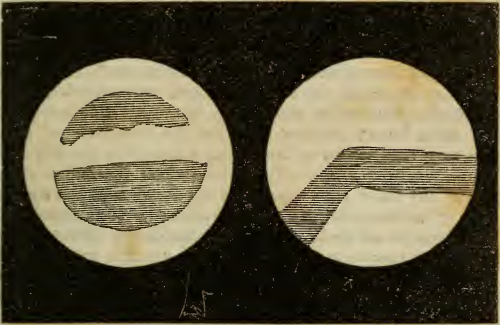
Fig. XLI. Fig. XLII.



My own views of this planet have not been numerous, as it is only at intervals of two years, when near its opposition, that observations can be made on its surface with effect. I have, however, distinctly perceived its surface as delineated in Figures XLIII. and XLIV. These observations were made in November and December, 1832, and in January, 1837, and the appearances were very nearly the same; but the spots as represented in the two figures were seen at different times, and were evidently on different hemispheres of the planet, which were presented in succession by its motion of rotation. The instrument used in the observations was a 44½ inch achromatic telescope, with magnifying powers of 150 and 180 times.

Besides the dark spots here delineated, there is a small portion of the globe of Mars, round its south pole, which has, at least occasionally, a much brighter appearance than the other parts. Maraldi, who made observations on Mars

Fig. XLIII. Fig. XLIV.



about the year 1719, says that this bright spot had been noticed for sixty years before that period, and that it is more permanent than any of the other spots of Mars; that this segment or zone is not all of equal brightness, more than one half of it being brighter than the rest; that the part which is least bright is subject to great changes, and has sometimes diappeared; and that there has sometimes been seen a similar luminous zone round the north pole of Mars, which has appeared of different brightness in different years. The bright spot at the polar point is represented at *a*, Figures XLI. and XLII. These white spots have been conjectured to be snow, as they disappear when they have been long exposed to the sun, and are greatest when just emerging from the long night of the polar winter in that planet. This is the opinion of Sir W. Herschel, in his paper on this subject in the Philosophical Transactions. "In the year 1781," says this astronomer, "the south polar spot was extremely large, which we might well expect, as that pole had but lately been involved in a whole twelvemonth's darkness and absence of the sun; but in 1783 I found it considerably smaller than before, and it decreased continually from the 20th of May till about the middle of September, when it seemed to be at a stand. During

this last period the south pole had already been about eight months enjoying the benefit of summer, and still continued to receive the sunbeams, though, towards the latter end, in such an oblique direction as to be but little benefited by them. On the other hand, in the year 1781, the north polar spot, which had then been its twelvemonth in the sunshine, and was but lately returning into darkness, appeared small, though undoubtedly increasing in size." Hence he concludes, "that the bright polar spots are owing to the vivid reflection of light from frozen regions, and that the reduction of those spots is to be ascribed to their being exposed to the sun."

Atmosphere of Mars.—From the gradual diminution of the light of the fixed stars when they approach near the disk of Mars, it has been inferred that this planet is surrounded with an atmosphere of great extent. Although the extent of this atmosphere has been much overrated, yet it is generally admitted by astronomers that an atmosphere of considerable density and elevation exists. Both Cassini and Roemer observed a star, at six minutes from the disk of Mars, become so faint before it was covered by the planet that it could not be seen even with a three feet telescope; which, in all probability, was caused by the light of the star being obscured by passing through the dense part of the atmosphere of the planet. It is doubtless owing to this circumstance that Mars presents so *ruddy* an appearance, more so than any other planet or star in the nocturnal sky. When a beam of light passes through a dense medium, its colour inclines to red, the other rays being partly reflected or absorbed. Thus the morning and evening clouds are generally tinged with red, and the sun, moon, and stars, when near the horizon, either rising or setting, uniformly assume a ruddy aspect, because their light then passes through the lower and denser part of our atmosphere. When the light of the sun passes through the atmosphere of Mars, the most refrangible colours, such as the violet, will be partly absorbed; and before the reflected rays reach the earth, they must again pass through the atmosphere of the planet, and be deprived of another portion of the most refrangible rays; and, consequently, the red rays will predominate, and the planet assume a dull red colour. This I conceive to be the chief reason why I could never perceive Mars in the daytime, even when in the most favourable position, so distinctly as Jupiter, although the

quantity of solar light which falls on this planet is more than eleven times greater than what falls on Jupiter; which seems to indicate that Jupiter is surrounded with a less dense and more transparent atmosphere. Sir W. Herschel, though he questions the accuracy of some of the observations of the dimness caused by the appulses of the fixed stars to this planet, yet admits that it has a considerable atmosphere. "For," says he, "besides the permanent spots on its surface, I have often noticed occasional changes of partial bright belts, and also once a darkish one in a pretty high latitude: and these alterations we can hardly ascribe to any other cause than the variable disposition of clouds and vapours floating in the atmosphere of the planet."

Conclusions respecting the Physical Constitution of Mars.—From the preceding observations and the views we have exhibited of this planet, I presume we are warranted to deduce, with a high degree of probability, the following conclusions: 1. That land and water, analogous to those on our globe, exist in the planet Mars. The dark spots are obviously the water or seas upon its surface, which reflect a much less proportion of the solar light than the land. "The seas," says Sir John Herschel, "by a general law in optics, appear *greenish*, and form a contrast to the land. I have noticed this phenomenon on many occasions, but never more distinct than on the occasion when the drawing was made;" from which the figure of Mars in his "Astronomy" is engraved. It is not improbable, from the size of the dark spots compared with the whole disk of Mars, that about one third or one fourth of the surface of that planet is covered with water. If this estimate be nearly correct, it will follow that the quantity of land and water on Mars is nearly in a reverse proportion to that which obtains on our globe, where the quantity of water is nearly four times greater than that of the land. The dark spots in some of the views given above seem to convey the idea of several large gulfs or bays running up into the land. The various appearances of these spots which we have delineated are partly owing to the different relations and positions in which they appear during different periods of the planet's rotation, as I have already shown would happen in the appearance of the earth were it viewed from a distance in the heavens (see page 111). 2. It is probable, too, that there are strata of clouds of considerable extent occasionally

floating in the atmosphere of Mars ; for some of the observers referred to above have remarked that some of the spots "changed their form in the course of a month ;" and Sir W. Herschel, as above stated, declares that he has noticed "occasional changes of partial bright belts, and also once of a darkish one." These, in all probability, were clouds of greater or less density, which, for the most part, would appear brighter than the seas by the reflection of the solar rays from their upper surfaces ; for although the *under* surface of dense clouds appears dark to us who view them from below, yet. were we to view their upper surface from a distance when the sun shines upon them, they would undoubtedly present a bright appearance by the reflection of the solar rays. It is doubtless owing to the occasional interposition of such clouds in the atmosphere of Mars that the *permanent* spots sometimes appear to vary their form and aspect. 3. A variety of seasons, somewhat similar to ours, must be experienced in this planet. The diversity of seasons on our globe arises chiefly from the inclination of its axis to the plane of the ecliptic. Now, in reference to Mars, the axis of rotation is inclined to its orbit at even a greater angle than that of the earth ; and, therefore, the contrast between its opposite seasons is probably more marked and striking than on the earth. The seasons will also continue for a much longer period than with us, as the year in Mars is nearly double the length of ours, so that summer and winter will be prolonged for a period of eight or nine months respectively. If the opinion of Sir W. Herschel be correct, that the white spots at the poles of Mars are caused by the reflection of the sun's rays from masses of ice and snow, it will afford an additional proof of the existence of a diversity of seasons on this planet, and that its inhabitants are subjected to a winter of great severity and of long duration. 4. This planet bears a more striking resemblance to the earth than any other planet in the solar system. Its distance from the sun, compared with that of the other superior planets, is but a little more than that of the earth. The distinction of land and water on its surface is more strikingly marked than on any of the other planets. It is encompassed with an atmosphere of considerable extent. It is probable that large masses of clouds are occasionally formed in that atmosphere, such as sometimes hover over the whole of Britain, and even of Europe, for several weeks at a time

The length of the day is nearly the same as ours, and it has evidently a succession of different seasons. Were we warranted from such circumstances to form an opinion respecting the physical and moral state of the beings that inhabit it, we might be apt to conclude that they are in a condition not altogether very different from that of the inhabitants of our globe.

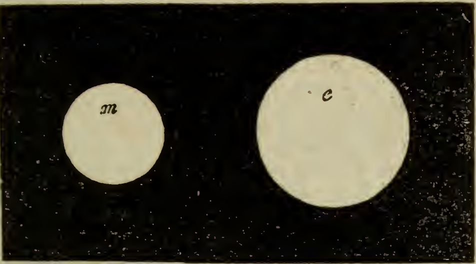
Magnitude and Extent of Surface of Mars.—This planet is now estimated to be about 4200 miles in diameter, which is only a little more than half the diameter of the earth. It contains 38,792,000,000, or more than 38 thousand millions of solid miles; and the number of square miles on its surface is 55,417,824, or more than-fifty five millions, which is about six millions of square miles more than on all the habitable parts of our globe. At the rate of population formerly stated, 280 to a square mile, it would contain a population of more than fifteen thousand five hundred millions, which is nineteen times the number of the inhabitants of the earth; but, as it is probable that one third of the surface of Mars is covered with water, should we subtract one third from these sums there would still remain accommodation for twelve times the number of the population of our globe.

No *moon* or secondary planet has yet been discovered about Mars; yet this is no proof that it is destitute of such an attendant; for as all the secondary planets are much less than their primaries, and as Mars ranks among the smallest planets of the system, its satellite, if any exist, must be extremely small. The second satellite of Jupiter is only the 1-43 part of the diameter of that planet; and a satellite bearing the same proportion to Mars would be only ninety-seven miles in diameter. But, suppose it were double this size, it could scarcely be distinguishable by our telescopes, especially when we consider that such a satellite would never appear to recede to any considerable distance from the margin of Mars. The distance of the first satellite of Jupiter is only three diameters of that planet from its centre; and the distance of the first satellite of Saturn is but one diameter and two thirds from its centre. Now, if a satellite of the size we have supposed were to revolve round Mars at the distance of only two or three of its diameters, its nearness to the body of Mars would generally prevent its being perceived, unless with telescopes of very great power and under certain favourable cir-

cumstances; and it could never be expected to be seen but about the time of that planet's opposition to the sun, which happens only at an interval of more than two years. If such a satellite exist, it is highly probable that it will revolve at the nearest possible distance from the planet, in order to afford it the greatest quantity of light; in which case it would never be seen beyond two minutes of a degree from the margin of the planet, and that only in certain favourable positions. If the plane of its orbit lay nearly in a line with our axis of vision, it would frequently be hidden either by the interposition of the body of Mars or by transiting its disk. It is therefore possible, and not at all improbable, that Mars may have a satellite, although it has not yet been discovered. It is no argument for the nonexistence of such a body that we have not yet seen it; but it ought to serve as an argument to stimulate us to apply our most powerful instruments to the regions around this planet with more frequency and attention than we have hitherto done, and it is possible our diligence may be rewarded with the discovery. The long duration of winter in the polar regions of Mars seems to require a moon to cheer them during the long absence of the sun; and if there be none, the inhabitants of those regions must be in a far more dreary condition than the Laplanders and Greenlanders of our globe.

Proportion of Light on the Surface of Mars.—As the quantity of solar light on any of the planets is in an inverse proportion to their distances from the sun, the quantity of light which falls upon Mars will be much less than that which we enjoy. It is nearly in the proportion of 43 to 100, which is less than one half of the light which falls upon the earth. This is partly the reason why Mars appears so much less brilliant than Venus, but it is not the only reason; for Jupiter appears much more brilliant than Mars, although he is placed at a much greater distance from the sun. The refraction, reflection, and absorption of the rays of light, in passing through the dense atmosphere to which we have alluded, form, doubtless, one principal reason why Mars appears more sombre in its aspect than Jupiter or Venus. The following figure represents the apparent size of the sun as seen from Mars and the earth. The circle *m* represents the size of the sun as seen from Mars, and *e* as seen from the earth. The degree of *heat* on different parts of this planet will depend

Fig. XLV



upon various circumstances; the inclination of its axis, the positions of places in respect to its equator and poles, the nature of its soil, the materials which compose its surface, the quantity of water in different regions, the constitution of its atmosphere, and other circumstances with which we are unacquainted.

The *figure* of Mars is an *oblate spheroid*, like that of the earth, but much flatter at the poles. Its equatorial diameter is to its polar as 1355 to 1272, or nearly as 16 to 15; consequently, if its equatorial diameter be 4200 miles, its polar diameter will be only 3937, which is 263 miles shorter than the equatorial. The *mass* of this planet compared with that of the sun is as 1 to 1,846,082. Its *density* compared with water is as 3 2-7 to 1, which is considerably less than that of the earth, but greater than the general density of the rocks and other materials which compose the surface of our globe. A body which weighs one pound on the surface of the earth would weigh only five ounces six drachms on the surface of Mars.

V. ON THE LATELY-DISCOVERED PLANETS VESTA, JUNO, CERES, AND PALLAS.

The immense interval which lies between the orbits of Mars and Jupiter led some astronomers to surmise that a planet of considerable magnitude might possibly exist some-

where within this limit. This conjecture was grounded on the intervals which exist between the rest of the planetary orbits. Between the orbits of Mercury and Venus there is an interval of 31,000,000 of miles; between those of Venus and the earth, 27,000,000; between those of the earth and Mars, 50,000,000; but between the orbits of Mars and Jupiter there intervenes the immense space of 349,000,000 of miles. Here the order of the solar system was supposed to be interrupted, which would form an exception to the general law of the proportion of the planetary distances. No planetary body, however, was detected within this interval till the beginning of the present century; and, instead of one large body, as was surmised, four very small ones have been discovered. These bodies are situated at a distance from Mars nearly corresponding to the order and proportion to which we have now alluded; and this circumstance leads to a belief "that it is something beyond a mere accidental coincidence, and belongs to the essential structure of the system." As these bodies are invisible to the naked eye, and can only be seen in certain favourable positions, and as only a short period has elapsed since their discovery, we are not yet much acquainted with many of their phenomena and physical peculiarities.

Of these four bodies, the first discovered was that which is now named *Ceres*, and sometimes *Piazzi*, from the name of its discoverer. It was discovered at Palermo, in the island of Sicily, on the 1st of January, 1801, or the first day of the present century, by Piazzi, a celebrated astronomer belonging to that city, who has since distinguished himself by his numerous observations on the fixed stars. This new celestial body was then situated in the constellation Taurus, and, consequently, at no very great distance from its opposition to the sun. It was observed by Piazzi till the 12th of February following, when a dangerous illness compelled him to discontinue his observations; but it was again discovered by Dr. Olbers, of Bremen, after a series of unwearied observations and laborious calculations, founded on a few insulated facts which had been stated by Piazzi. Dr. Brewster states, in the "Edinburgh Encyclopædia," vol. ii., p. 638, and likewise in his second edition of "Ferguson's Astronomy," vol. ii., p. 38, "that the rediscovery of this planet by Olbers did not take place till the 1st of January, 1807;" which must be a mistake,

tor in "*La Decade Philosophique*" for July, 1803, it is stated that Dr. Olbers, some time before, received La Lande's prize for having discovered the planet Pallas; and, at the same time, his merit is referred to in having rediscovered Ceres, and having been among the first that announced it to the world. Besides, Sir W. Herschel has observations on this planet in the "Philosophical Transactions," of date February 7, 1802 which, of course, was posterior to Dr. Olbers's rediscovery.

The planet *Pallas*, or, as it is sometimes named, *Olbers* was discovered on the 28th of March, 1802, only fifteen months after the discovery of Ceres, by Dr. Olbers, a physician at Bremen, in Lower Saxony, distinguished for his numerous celestial observations, and for his easy and commodious method of calculating the orbits of comets. The plane *Juno* was discovered on the evening of September 1, 1804, within two years and a half of the discovery of Pallas, by M. Harding, at the observatory of Lilienthal, near Bremen, while endeavouring to form an atlas of all the stars near the orbits of Ceres and Pallas, with the view of making farther discoveries. While thus engaged, he perceived a small star of about the eighth magnitude, which was not marked in the Celestial Atlas of La Lande, which he put down in his chart. Two days afterward he found that the star had disappeared from the position in which he had marked it; but a little to the southwest of that position he perceived another star resembling it in size and colour; and having observed it again on the 5th of September, and finding that it had moved a little in the same direction as before, he concluded that it was a moving body connected with the solar system.

The planet *Vesta* was discovered on the 29th of March, 1807, little more than two years and a half after the discovery of Juno, so that four primary planets belonging to our system, which had been hidden for thousands of years from the inhabitants of our globe, were discovered within the space of little more than six years. Vesta must then have been near its opposition. The discovery of Vesta was made by Dr. Olbers, who had previously discovered Pallas, and rediscovered Ceres. He had formed an idea that the three small bodies lately discovered might possibly be the fragments of a larger planet, whicn had been burst asunder by some unknown and powerful irruptive force proceeding from its interior parts, and that more fragments might still be detected. Whether this opinion be ten-

able or not, it seems to have led to the discovery of Vesta; for the doctor concluded, if his opinion were just, that although the orbits of all these fragments might be differently inclined to the ecliptic, yet, *as they must all have diverged from the same point*, "they ought to have two common points of reunion, or *two nodes in opposite regions of the heavens*, through which all the planetary fragments must sooner or later pass." One of these nodes, or points of intersection of the orbits, he found to be in the sign *Virgo*, and the other in the constellation of the *Whale*; and it was actually in the regions of the Whale that the planet Juno was discovered by M. Harding. With the view, therefore, of detecting other fragments, if any should exist, Dr. Olbers examined, three times every year, all the small stars in the opposite constellations of Virgo and the Whale, and in the constellation *Virgo* the planet Vesta was first seen.* This was doubtless a remarkable coincidence of theory with observation, and af-

* William Olbers, M.D., the discoverer of Vesta and Pallas, was born on the 11th of October, 1758, at Arbergen, a village in the Duchy of Bremen, where his father was a clergyman. His father, besides being a man of great general learning, was a good mathematician and a lover of astronomy. Young Olbers, when in his fourteenth year, felt a great taste for that science. During an evening walk in the month of August, having observed the Pleiades, or seven stars, he became very desirous of knowing to what constellation they belonged. He therefore purchased some charts and books, and began to study this science with the greatest diligence; he read with the greatest avidity every astronomical work he was able to procure, and in a few months made himself acquainted with all the constellations. Finding that a knowledge of mathematics was necessary to the study of astronomy, he devoted all his leisure time to this subject. He was at the same time engaged in the study of medicine as a profession. In the year 1779, when scarcely twenty-one years of age, he observed at Gottingen, and calculated the first comet. An account of this labour was published in the "Berlin Astronomical Calendar" for 1782, where it is mentioned that Olbers made his construction one night while attending a patient; and yet it was afterward found that his determination of this orbit corresponded with the most accurate elements of the comet which were calculated. Since that period, the astronomy of comets has been his favourite study, and it is admitted that none of the methods formerly tried for calculating the orbit of a comet is so simple, and, at the same time, so elegant as that of Dr. Olbers. When at Vienna, amid all his applications to the study of medicine, he was the first who observed the planet Uranus (after its discovery by Herschel) on the 17th of August, 1781. On the 19th he perceived its motion, and continued his observations till the end of September, at which period it was considered as a comet. Returning from the scene of his studies, he settled at Bremen as a physician, where he soon acquired the confidence of his fellow-citizens, both on account of his successful practice and integrity and affability of his character.

fords a presumption that the conjecture of this eminent astronomer may possibly have a foundation in fact.

The following is a summary of what has been ascertained respecting the distances, magnitudes, and motions of these bodies :—

The Planet Vesta.—The mean distance of this planet from the sun is reckoned to be about 225 millions of miles; its annual revolution is completed in about 3 years 7 1-2 months, or in 1325 days; the circumference of its orbit is 1414 millions of miles, and, of course, it moves with a velocity, on an average, of more than 44,000 miles an hour. The inclination of its orbit to the plane of the ecliptic is seven degrees, eight minutes; and its eccentricity 21 millions of miles. The diameter of this planet has been estimated by some astronomers at only about 270 miles; and, if this estimate be correct, it will contain only 229,000 square miles, or a surface somewhat less than Great Britain, France, and Ireland; and, according to the rate of population formerly stated, would contain 64 millions of inhabitants, or about five times the number of the inhabitants of the United States of America, or nearly the twelfth part of the population of the earth. It is probable, however, that this estimate is too small, and that the apparent diameter of this planet has not yet been accurately taken; for the light of this body is considered equal to that of a star of the fifth or sixth magnitude, and it may sometimes be distinguished in a clear evening by the naked eye. Its light is more intense and white than that of either Ceres, Juno, or Pallas; and it is not surrounded with any nebulosity, as some of these planets are. It is not likely that a body of this size could be seen at the distance of 130 millions of miles, which is its nearest approach to the earth, and that, too, by the naked eye (as Schroeter affirms he did several times), unless the substances on its surface were of such a nature as to reflect the solar rays with a far greater degree of brilliancy than any of the other planets. The diameter of the third satellite of Jupiter is reckoned at 3377 miles, and its surface, of course, contains 35,827,211 square miles, which is 156 times greater than the *surface* of Vesta, according to the above estimation. Yet this satellite can never (or, at least, but rarely) be seen by the naked eye. Vesta is, indeed, only about one third the distance from us of the satellite of Jupiter; but, making allowance for this circumstance, it

should be at least twenty times larger *in surface* than is estimated above in order to be seen by the naked eye, or with the same distinctness as the third satellite of Jupiter. In other words, it should have a diameter of at least 1200 miles. If this is not the case, there must be something very peculiar and extraordinary in the reflective power of the materials which compose its surface to produce such an intensity of light from so small a body at so great a distance as 130 millions of miles. I am therefore of opinion that the size of this planet has not yet been accurately ascertained, and that future and more accurate observations are still requisite to determine its apparent diameter and real magnitude.

The Planet Juno.—The next planet in the order of the system is Juno. Its distance from the sun is estimated at 254 millions of miles. The circumference of its orbit is 1596 millions of miles. Through this circuit it moves in four years and 128 days, at the rate of 41,850 miles every hour. Its diameter, according to the estimate of Schroeter, is 1425 English miles. Its surface will therefore contain six millions, three hundred and eighty thousand square miles, and a population of one thousand, seven hundred and eighty-six millions, which is more than double the number of the earth's inhabitants. The orbit of Juno is inclined to the ecliptic in an angle of thirteen degrées, three minutes. Its eccentricity is 63,588,000 miles, so that its greatest distance from the sun is 316,968,000 miles, while its least distance is only 189,792,000. Its apparent diameter as seen from the earth is little more than three seconds. This planet is of a reddish colour, and is free from any nebulosity ; yet the observations of Schroeter render it probable that it has an atmosphere more dense than that of any of the old planets of the system. A remarkable variation in the brilliancy of this planet has been observed by this astronomer, which he attributes to changes that are going on in its atmosphere, and thinks it not improbable that these changes may arise from a diurnal rotation performed in twenty-seven hours.

The Planet Ceres.—This planet is about 263 millions of miles from the sun, and completes its annual revolution in four years, seven months, and ten days. The circumference of its orbit is 1653 millions of miles, and it moves at the rate of about forty-one thousand miles an hour. The eccentricity of its orbit is 20,598,000 miles. Its greatest distance

from the sun is 283,500,000 miles, and its least distance 242,300,000. Its apparent mean diameter, including its atmosphere, according to Schroeter, is somewhat more than six seconds at its mean distance from the earth. Its real diameter, according to the estimate of the same astronomer, is 1624 English miles; but, including its atmosphere, is 2974 miles. Its surface, therefore, contains 8,285,580 square miles, or about the one sixth part of the habitable portions of our globe; and would afford accommodation for 2,319,962,400, or more than 2300 millions of inhabitants, according to the rate of population in England, which is nearly triple the present population of the earth. This planet is of a slight ruddy colour, and appears about the size of a star of the eighth magnitude, and is consequently invisible to the naked eye. It seems to be surrounded with a dense atmosphere, and exhibits a disk or sensible breadth of surface when viewed with a magnifying power of two hundred times. Schroeter has determined, from a great number of observations, that its atmosphere is about six hundred and seventy-five English miles in height, and that it is subject to numerous changes. Like the atmosphere of the earth, it is very dense near the planet, and becomes rarer at a greater distance, which causes its apparent diameter to appear somewhat variable. When this planet is approaching the earth, towards the point of its opposition to the sun, its diameter increases more rapidly than it ought to do from the diminution of its distance, which Schroeter supposes to arise from the finer exterior strata of its atmosphere becoming visible while it approaches the earth. He also perceived that the visible hemisphere of the planet was sometimes overshadowed, and at other times cleared up, so that he concludes there is little chance of discovering the period of its diurnal rotation. The inclination of its orbit to the ecliptic is in an angle of ten degrees, thirty-seven minutes. The intensity of light upon its surface is more than seven times less than what we enjoy.

Sir William Herschel, in the year 1802, after the discovery of Ceres and Pallas, made a number of observations to ascertain if any of these bodies were accompanied with satellites. Several very small stars were occasionally perceived near Ceres with high magnifying powers, of the positions and motions of which he has given several delineations; but it did not appear probable, in subsequent observations, that they ac-

companied the planet. In his observation of April 28, with a power of 550, he says, "Ceres is surrounded with a strong haziness. The breadth of the coma, beyond the disk, may amount to the extent of a diameter of the disk, which is not very sharply defined. Were the whole coma and star taken together, they would be at least three times as large as my measure of the star. The coma is very dense near the nucleus; but loses itself pretty abruptly on the outside, though a gradual diminution is still very perceptible." These observations seem to corroborate the idea that Ceres is encompassed with an atmosphere of great density and elevation.

The Planet Pallas.—This planet revolves about the sun at the mean distance of two hundred and sixty-three millions of miles, and finishes its revolution in 1681 days, 17 hours, or in four years and seven and one third months, which is within a day of the time of the revolution of Ceres. Its distance is likewise nearly the same as that planet, and the circumference of its orbit will also be nearly the same. This planet, however, is distinguished in a remarkable degree both from Ceres and from all the other planets by the very great inclination of its orbit to the plane of the ecliptic. This inclination is no less than thirty-four degrees, thirty-seven minutes, or nearly five times the inclination of Mercury's orbit, which was formerly reckoned to have the greatest inclination of any of the planetary orbits. The *eccentricity* of the orbit of Pallas is likewise greater than that of any of the other planets, being no less than 64,516,000 miles, so that this planet is 129,000,000 of miles nearer the sun in one part of its orbit than it is at the opposite extremity. Its greatest distance from the sun is 327,437,000 miles, and its least distance only 198,404,000 miles. Of course, its rate of motion in its orbit must be very variable, sometimes moving several thousands of miles an hour swifter at one time than at another, which is likewise the case, in a remarkable degree, with the planet Juno. Its *mean motion* is about 41,000 miles an hour.

This planet presents a ruddy aspect, but less so than that of Ceres. It is likewise surrounded with a nebulosity somewhat like that of Ceres, but of less extent. The following are some of the observations of this planet by Schroeter and Herschel. The atmosphere of Pallas, according to Schroeter, is to that of Ceres as one hundred and one to one hundred and forty-six, or nearly as two to three. It undergoes simi-

lar changes, but the light of the planet exhibits greater variations. On the 1st of April the atmosphere of Pallas suddenly cleared up, and the solid nucleus or disk of the planet was alone visible. About twenty-four hours afterward the planet appeared pale and surrounded with fog, and this appearance continued during the 3d and 4th of April; but this phenomenon was not considered as arising from the diurnal rotation of the planet. The following are Herschel's observations: "April 22. In viewing Pallas, I cannot, with the utmost attention and under favourable circumstances, perceive any sharp termination which might denote a disk; it is rather what I would call a nucleus. April 22. The appearance of Pallas is cometary; the disk, if it has any, being ill-defined. When I see it to the best advantage, it appears like a much-compressed, extremely small, but ill-defined planetary nebula. May 1. With a twenty feet reflector, power 477, I see Pallas well, and perceive a very small disk, with a coma of some extent about it, the whole diameter of which may amount to six or seven times that of the disk alone."—*Philosophical Transactions* for 1802.

The diameter of this planet has not, perhaps, been ascertained with sufficient precision. The difference in the estimates formed by Sir W. Herschel and M. Schroeter is very great. According to Schroeter, the diameter of Pallas is 2099 miles. If this estimate be nearly correct, Pallas will be about the size of our moon, and will comprehend on its surface nearly fourteen millions of square miles, which would accommodate a population of nearly four thousand millions, or five times the population of our world. The apparent mean diameter of this planet, comprehending its atmosphere, at its mean distance from the earth, according to Schroeter, is six and a half seconds.

Such is a brief view of the principal facts which have been ascertained respecting the planets Vesta, Juno, Ceres, and Pallas. All these bodies are situated between the orbits of Mars and Jupiter, and they are all invisible to the naked eye, except, perhaps, the planet Vesta, when in certain favourable positions. The real magnitudes of these planets are not to be considered as yet accurately determined; they may be a little greater or less than what is stated above, though it is not probable they are much larger. It may not be improper to remark, that on this point there is a great difference in the

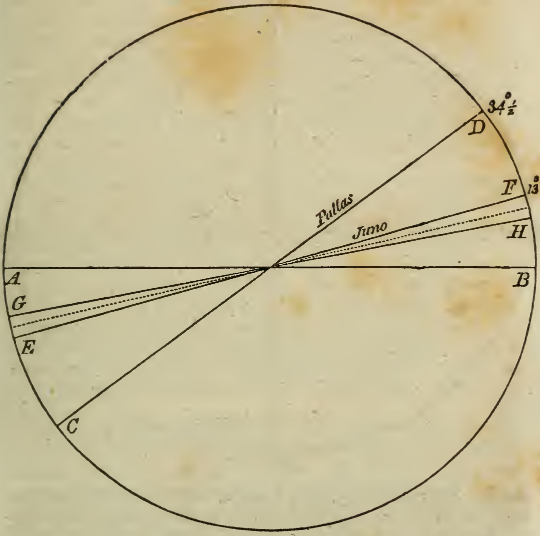
estimates of Schroeter and Herschel, the two principal observers who have investigated the phenomena of these planets, owing to the mode in which they measured the apparent diameters of these bodies. According to Sir W. Herschel, there is none of these bodies that exceeds 163 miles in diameter. But it is obvious, from the considerations I have stated in the description of Vesta, that bodies of such a small size could not be visible at such a distance, unless they were either luminous or composed of matter fitted to reflect the solar light with an extraordinary degree of brilliancy ; and therefore it is far more probable that the estimates of Schroeter are nearest the truth.

Peculiarities of the New Planets.—These bodies present to our view various singularities and anomalies, which, at first sight, appear incompatible with the proportion and harmony which we might suppose originally to have characterized the arrangements of the solar system. In the first place, *their orbits have a much greater degree of inclination to the ecliptic than those of the old planets.* The orbit of Venus is inclined to the ecliptic in an angle of three degrees, twenty minutes ; of Mars, one degree, fifty-one minutes ; of Jupiter, one degree, eighteen minutes ; of Saturn, two degrees and a half ; and of Uranus, only forty-six minutes. But the inclination of the orbit of Vesta is seven degrees, nine minutes ; of Juno, thirteen degrees ; of Ceres, ten degrees, thirty-seven minutes ; and of Pallas, no less than thirty-four degrees and a half, which is nineteen times greater than the inclination of Mars, and twenty-seven times greater than that of Jupiter. The proportion of these inclinations is represented in the following figure. (See *Fig.* XLVI.)

Let *A B* represent the plane of the ecliptic, and the line *C D* will represent the inclination of the orbit of Pallas= 34 1-2 degrees ; *E F*, the inclination of the orbit of Juno= 13 degrees ; *G H*, the inclination of Vesta's=7 degrees ; and the dotted line the inclination of Ceres=10 1-2 degrees. All the older planets have their orbits much less inclined to the ecliptic, except Mercury, which has nearly the same inclination as Vesta ; so that the zodiac would now require to be extended nearly five times its former breadth in order to include the orbits of all the planets.

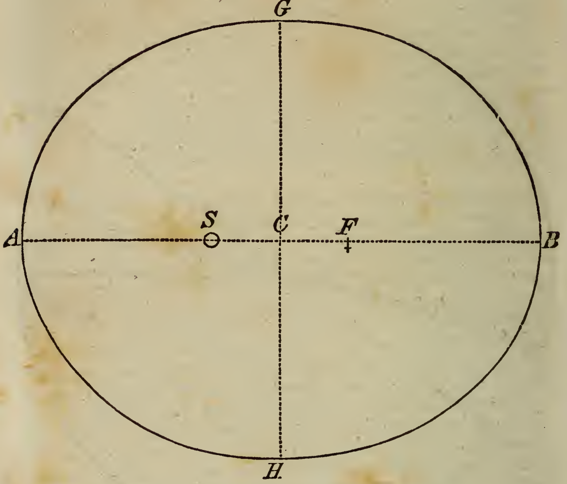
2. *The orbits of these planets are in general more eccentric than those of the other planets ;* that is, they move in longer

Fig. XLVI.



and narrower ellipses. The following figure nearly represents the orbit of Pallas, and the orbit of Juno is nearly similar. *S* represents the sun in one of the foci of the ellipse; *C* the centre; *F* the upper focus of the ellipse; and the whole line *A B* the transverse diameter. Now the distance, *S C*, from the sun to the centre, is the *eccentricity* of the orbit. This eccentricity, in the case of Pallas, amounts to more than sixty-four and a half millions of miles. Consequently, when the planet is at *B*, which is called its *Aphelion*, or greatest distance from the sun, it is double its eccentricity, or the whole length of the line *S F* farther from the sun than when t is at the point *A*, which is called its *Perihelion*, or least

Fig. XLVII.



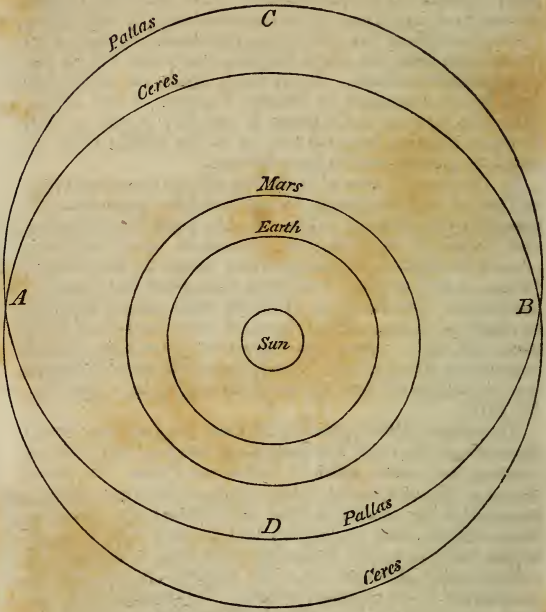
distance from the sun, that is, it is 129 millions of miles farther from the sun in the one case than in the other, which is nearly *one fourth* of the whole transverse diameter of the orbit *A B*. Consequently, its motion will be much slower by several hundreds of thousands of miles a day when near the point *B*, its aphelion, than when near its perihelion at the point *A* ; and to a spectator on its surface the sun will appear more than double the size from the point *A* that he does from the point *B* ; and its inhabitants (if any) will experience a greater difference in the intensity of the solar light which falls upon them in different periods of its year, than there is between Venus and the earth, or between the earth and Mars. On the other hand, the eccentricity of the orbits of the older planets is comparatively small. The eccentricity of the orbit of Venus is less than half a million of miles, which is only the 1-274 part of

the transverse diameter of its orbit. The Earth's eccentricity is 1,618,000 miles, or the 1-119 part; Jupiter's, 1-43 part; Saturn's, 1-38 part; and that of Uranus, about 1-43 part; whereas the eccentricities of Pallas and Juno amount to nearly *one eighth* part of the transverse axes of their orbits Were the orbits of the old planets represented by figures ten times larger than the above diagram, they could not be distinguished from circles. In the above figure, the dotted line *G H* is the *conjugate* or shorter diameter of the ellipse. When the planet is at the points *G* and *H*, it is said to be at its *mean distance* from the sun, or at the middle point between its greatest and its least distance.

3. *The orbits of several of the new planets cross each other.*—This is a very singular and unaccountable circumstance in regard to the planetary orbits. It had been long observed that comets, in traversing the heavens in every direction, crossed the orbits of the planets; but, before the discovery of Pallas, no such anomaly was found throughout the system of the planets. For the orbits of all the other planets approach so nearly to circles, and are separated from each other by so many millions of miles, that there is no possibility of such intersection taking place. The following diagram represents the intersection of the orbits of Ceres and Pallas. (See *Fig.* XLVIII.)

The central circle represents the sun; the two next circles the orbits of the earth and Mars; and the two outer circles, crossing each other, those of Ceres and Pallas. In consequence of this intersection of their orbits, there is a *possibility*, especially if the periods of their revolutions were somewhat more different from each other, that the two planets might happen to strike against each other were they to meet at the points *A* and *B*, where the orbits intersect, a very singular contingence in the planetary system. It is owing to the very great eccentricity of the orbit of Pallas that it crosses the orbit of Ceres. It is several millions of miles nearer the sun in its perihelion (or at *A*, Fig. XLVII.) than Ceres, when in the same point of its orbit. But when Pallas is in its aphelion (or at *B*, Fig. XLVII.), its distance from the sun is several millions of times greater than that of Ceres in the same point of its orbit. Suppose its aphelion at *C*, Fig. XLVIII.; it is farther from the sun than Ceres, and nearer at *D* its perihelion. The same things happen in the case of the other two

Fig. XLVIII.



planets, particularly Vesta. Juno is farther from the sun at its aphelion than Ceres in the same point of its orbit, and Vesta is farther from the sun in its aphelion than either Juno, Ceres, or Pallas in their perihelions. The perihelion distance of Vesta is greater than that of Juno or Pallas. Hence it follows that Vesta may sometimes be at a greater distance from the sun than either Juno, Ceres, or Pallas, although its mean distance is less than that of either of them by twenty-

eight millions of miles; so that *the orbit of Vesta crosses the orbits of all the other three*, and therefore it is a *possible* circumstance that a collision might take place between Vesta and any of these three planets, were they ever to meet at the intersection of their orbits. Were such an event to happen, it is easy to foresee the catastrophe that would take place. If the collision of two large ships, sailing at the rate of ten miles an hour, be so dreadful as to shatter their whole frame and sink them in the deep, what a tremendous shock would be encountered by the impulse of a ponderous globe, moving at the rate of forty thousand miles an hour? A universal disruption of their parts and a derangement of their whole constitution would immediately ensue; their axes of rotation would be changed; their courses in their orbits altered; fragments of their substance tossed about through the surrounding void, and the heavens above would appear to run into confusion. Though we cannot affirm that such an event is impossible or will never happen, yet we are sure it can never take place without the permission and appointment of Him who at first set these bodies in motion, and who superintends both the greatest and the most minute movements of the universe.

4. Another peculiarity in respect to these planets is, that *they revolve nearly at the same mean distances from the sun.* The mean distance of Juno is 254 millions of miles; that of Ceres, 262,903,000; and that of Pallas, 262,901,000, which is almost the same as Ceres. This is a very different arrangement from that of the other planets, whose mean distances are immensely different from each other; Mars being 50 millions of miles from the orbit of the earth, and 80 millions from the orbits of any of the new planets; Jupiter, 270 millions from Pallas; Saturn, 412 millions from Jupiter; and Uranus, 900 millions from Saturn. Except in the case of the new planets, the planetary system appears constructed on the most ample and magnificent scale, corresponding to the unlimited range of infinite space of which it forms a part.

5. These new planetary bodies *perform their revolutions in nearly the same periods.* The period of Vesta is 3 years, 7½ months; that of Juno, 4 years, 4½ months; of Ceres, 4 years, 7⅓ months; and of Pallas, 4 years, 7⅓ months. So that there are only three months of difference between the periods of Juno and Ceres, and scarcely the difference of a

single day between those of Ceres and Pallas; whereas the periods of the other planets differ as greatly as their distances. The period of Mercury is about 3 months; of Venus, 7½ months; of Mars, nearly 2 years; of Jupiter, 12 years; of Saturn, 29½; and of Uranus, nearly 84 years. A planet moving round the sun in almost the same period, and at the same distance as another, is a singular anomaly in the solar system, and could scarcely have been surmised by former astronomers.

6. Another singularity is, that these bodies *are all much smaller than the other planets*. Mercury was long considered as the smallest primary planet in the system, but it is nearly four times larger in surface than Ceres, and contains eight times the number of solid miles. Mars, the next smallest planet, is seventeen times larger than Ceres; and Jupiter, the largest of the planets, is 170,000 times larger than Ceres when their cubical contents are compared. The planets Vesta and Juno are smaller than Ceres, and Pallas is only a small degree larger. It is probable that all these four bodies are less in size than the secondary planets, or the satellites of Jupiter, Saturn, and Uranus.

Conclusions respecting the Nature of the New Planets.—The anomalies and peculiarities of these bodies, so very different from the order and arrangement of the older planets, open a wide field for reflection and speculation. Having been accustomed to survey the planetary system as a scene of proportion, harmony, and order, we can scarcely admit that these bodies move in the same paths, and are arranged in the same order as when the system was originally constructed by its Omnipotent Contriver. As we know that changes have taken place in our sublunary region since our globe first came from the hands of its Creator, so it is not contrary either to reason or observation to suppose that changes and revolutions, even on an ample scale, may take place among the celestial orbs. We have no reason to believe in the "incorruptibility" of the heavenly orbs, as the ancients imagined, for the planets are demonstrated to be *opaque* globes as well as the earth; they are diversified with mountains and vales, and, in all probability, the materials which compose their surfaces and interior are not very different from the substances which constitute the component parts of the earth. I have already alluded to the opinion of Dr. Olbers, that the new planets are only the frag-

ments of a larger planet which had been burst asunder by some immense irruptive force proceeding from its interior parts. However strange this opinion may at first sight appear, it ought not to be considered as either very improbable or extravagant. We all profess to admit, on the authority of Revelation, that the earth was arranged in perfect order and beauty at its first creation; and on the same authority we believe that its exterior crust was disrupted; that "the cataracts of heaven were opened, and the fountains of the great deep broken up," and that a flood of waters ensued which covered the tops of the loftiest mountains, which transformed the earth into one boundless ocean, and buried the immense myriads of its population in a watery grave. This was a catastrophe as tremendous and astonishing as the bursting asunder of a large planet. Although physical agents may have been employed in either case to produce the effect, yet we must admit, in consistency with the Divine perfections, that no such events could take place without the direction and control of the Almighty; and that, when they do happen, whatever appalling or disastrous effects they may produce, they are in perfect consistency with the moral laws by which his universal government is directed.

We know that a moral revolution has taken place among the human race since man was created, and that this revolution is connected with most of the physical changes that have happened in the constitution of our globe; and, if we believe the sacred historian, we must admit that the most prominent of these physical changes or concussions was the consequence or punishment of man's alienation from God and violation of his laws. As the principles of the Divine government must be essentially the same throughout every part of the boundless empire of the Almighty, what should hinder us from concluding that a moral cause, similar to that which led to the physical convulsions of our globe, may have operated in the regions to which we allude, to induce the Governor of the universe to undermine the constitution, and to dash in pieces the fabric of that world? The difference is not great between bursting a planet into a number of fragments and cleaving the solid crust of the earth asunder, removing rocks and mountains out of their place, and raising the bed of the ocean from the lowest abyss, so as to form a portion of elevated land; all which changes appear to have been effected in the by-past revolutions

of our globe, and both events are equally within the power and the control of Him "who rules in the armies of heaven and among the inhabitants of the earth," whatever physical agents he may choose to select for the accomplishment of his purposes. In the course of the astronomical discoveries of the two preceding centuries, views of the universe have been laid open which have tended to enlarge our conceptions of the attributes of the Deity, and of the magnificence of that universe over which he presides: and who knows but that the discovery of those new planets described above, and the singular circumstances in which they are found, are intended to open to our view a new scene of the physical operations of the Creator, and a new display of the operations of his moral government? For all the manifestations of God in his works are doubtless intended to produce on the mind not only an intellectual, but also a *moral* effect; and in this view the heavens ought to be contemplated with as much reverence as the revelations of his word. As the great Sovereign of the universe is described by the inspired writers as being the "King Eternal and *Invisible*," so we can trace his perfections and the character of his moral government only, or chiefly, through the medium of those displays he gives of himself in his wonderful operations both in heaven and on earth. And since, in the course of his providence, he has crowned with success the inventive genius of man, and led him on to make the most noble discoveries in reference to the amplitude and grandeur of his works, we have every reason to conclude that such inventions and such discoveries, both in the minute parts of creation and in the boundless sphere of the heavens, are intended to carry forward the human mind to more expansive views of his infinite attributes, of the magnificence of his empire, and of the *moral economy* of the government which he has established throughout the universe.

The hypothesis of the bursting of a large planet between Mars and Jupiter accounts in a great measure, if not entirely, for the anomalies and apparent irregularities which have been observed in the system of the new planets; and if this supposition be not admitted, we cannot account, on any principle yet discovered, for the singular phenomena which these planets exhibit. Sir David Brewster, who has entered into some particular discussions on this subject, after stating the remarkable coincidences between this hypothesis and actual observa-

tion, concludes in the following words: "These singular resemblances in the motions of the greater fragments and in those of the lesser fragments, and the striking coincidence between theory and observation in the eccentricity of their orbits, in their inclination to the ecliptic, in the position of their nodes, and in the places of their aphelia, are phenomena which could not possibly result from chance, and which concur to prove, with an evidence amounting almost to demonstration, that the four new planets have diverged from one common node, and have therefore composed a single planet."

Another species of phenomena, on which a great mystery still hangs, might be partly elucidated were the above hypothesis admitted, and that is, the singular but not well-attested fact of large masses of solid matter falling from the higher regions of the atmosphere, or what are termed *meteoric stones*. Few things have puzzled philosophers more than to account for large fragments of compact rocks proceeding from regions beyond the clouds, and falling to the earth with great velocity. These stones sometimes fall during a cloudy, and sometimes during a clear and serene atmosphere; they are sometimes accompanied with explosions, and sometimes not. The following statements, selected from respectable authorities, will convey some idea of the phenomena peculiar to these bodies. The first description I shall select is given by J. L. Lyons, Esq., F.R.S., and contained in the "Transactions of the Royal Society." It is entitled, "Account of the Explosion of a Meteor, near Benares, in the East Indies, and of the falling of some Stones at the same time." The following are only the leading particulars. "A circumstance of so extraordinary a nature as the fall of stones from the heavens could not fail to excite the wonder and to attract the attention of every inquisitive mind. On the 19th of December, 1798, about eight o'clock in the evening, a very luminous meteor was observed in the heavens by the inhabitants of Benares and the parts adjacent, in the form of a large ball of fire; it was accompanied by a loud noise resembling thunder, and a number of stones fell from it about fourteen miles from the city of Benares. It was observed by several Europeans, as well as natives, in different parts of the country. It was likewise very distinctly observed by several European gentlemen and ladies, who described it as a large ball of fire, accompanied with a loud rumbling noise not unlike an ill-discharged

platoon of musketry. It was also seen and the noise heard by several persons at Benares. When a messenger was sent next day to the village near which they had fallen, he was told that the natives had either broken the stones to pieces, or given them to the native collector and others. Being directed to the spot where they fell, he found four, most of which the fall had buried six inches deep in the earth. He learned from the inhabitants that, about eight o'clock in the evening, when retired to their habitations, they observed a very bright light, proceeding as from the sky, accompanied with a loud clap of thunder, which was immediately followed by the noise of heavy bodies falling in the vicinity. They did not venture out to make any inquiries till next morning, when the first circumstance that attracted their attention was the appearance of the earth being turned up in several parts of their fields, where, on examination, they found the stones. Several other stones of the same description were afterward found by different persons. One of these stones, of about two pounds' weight, fell through the top of the watchman's hut, close to which he was standing, and buried itself several inches in the floor, which was of consolidated earth. The form of the more perfect stones appeared to be that of an irregular cube, rounded off at the edges, but the angles were to be observed on most of them. At the time when the meteor appeared the sky was perfectly serene ; not the smallest vestige of a cloud had been seen since the 11th of the month, nor were any observed for many days after. It is well known there are no volcanoes on the continent of India, and therefore they could not derive their origin from any such source ; and no stones have been met with in the earth, in that part of the world, which bear the smallest resemblance to those now described."

On the 13th of December, 1795, a stone weighing fifty-six pounds fell near Wold cottage, in Yorkshire, at three o'clock P.M. It penetrated through twelve inches of soil and six inches of solid chalk rock, and, in burying itself, had thrown up an immense quantity of earth to a great distance ; as it fell, a number of explosions were heard as loud as pistols. In the adjacent villages the sound was heard as of great guns at sea ; but at two adjoining villages the sounds were so distinct of something passing through the air to the residence of Mr. Topham, that five or six people came up to see if anything extraordinary had happened at his house. When the

stone was extracted, it was warm, smoked, and smelt very strong of sulphur. The day was mild and hazy, but there was no thunder nor lightning the whole day. No such stone is known in the country, and there is no volcano nearer than Vesuvius or Hecla. The constituent parts of this stone were found exactly the same as those of the stones from Benares.*

On the 26th of April, 1803, an extraordinary shower of stones happened at L'Aigle, in Normandy. About one o'clock, the sky being almost serene, a rolling noise like that of thunder was heard, and a fiery globe of uncommon splendour was seen, which moved through the atmosphere with great rapidity. Some moments after there was heard at L'Aigle, and for thirty leagues round in every direction, a violent explosion, which lasted five or six minutes; after which was heard a dreadful rumbling like the beating of a drum. In the whole district there was heard a hissing noise like that of a stone discharged from a sling, and a great many mineral masses, exactly similar to those distinguished by the name of *meteor stones*, were seen to fall. The largest of these stones weighed seventeen pounds and a half. The Vicar of St. Michael's observed one of the stones fall with a hissing noise at the feet of his niece in the courtyard of his parsonage, and that it rebounded more than a foot from the pavement. When it was taken up and examined, it was found to resemble the others in every respect. As a wire manufacturer was working with his men in the open air, a stone grazed his arm and fell at his feet, but it was so hot that, on attempting to take it up, he instantly let it fall again. The celebrated Biot was deputed by government to repair to the spot and collect all the authentic facts in relation to this phenomenon, an account of which was afterward published in a long memoir. He found that almost all the residents of twenty hamlets declared that they were eyewitnesses of the shower of stones which was darted from the meteor. The interior parts of these stones resembled those of all the meteorites analyzed by Messrs. Howard and Vanquelin, such as those described above. They all contain silica, magnesia, oxyd of iron, nickel, and sulphur, in various proportions. Their specific gravity is about three and one third or three and one half times heavier than water.

The following are a few brief statements in relation to this

* See a long paper on this subject, by E. Howard, Esq., F.R.S., in "Transactions of the Royal Society of London" for 1802.

subject. In 1492, November 7, a stone of 260 lib. fell at Ensisheim, in Alsace. It is now in the library of Colmar, and has been reduced to 150 lib., in consequence of the abstraction of fragments. The famous Gassendi relates that a stone of a black metallic colour fell on Mount Vaïsion, in Provence, November 29, 1637. It weighed 54 lib., and had the size and shape of the human head. Its specific gravity was three and one half times that of water. 1654, March 30: A small stone fell at Milan and killed a Franciscan. 1706, June 7: A stone of 72 lib. fell at Larissa, in Macedonia; it smelled of sulphur, and was like the scum of iron. 1751, May 26: Two masses of iron, of 71 lib. and 16 lib., fell in the district of Agram, the capital of Croatia. The largest of these is now in Vienna. 1790, July 24: A great shower of stones fell at Barbotan, near Roquefort, in the vicinity of Bourdeaux. A mass, fifteen inches in diameter, penetrated a hut and killed a herdsman and a bullock. Some of the stones weighed 25 lib., and others 30 lib. July, 1810: A large ball of fire fell from the clouds at Shahabad, which burned five villages, destroyed the crops, and killed several men and women. November 23, 1810: Three stones fell in the commune of Charionville and neighbourhood of Orleans. These stones were precipitated perpendicularly, and without the appearance of any light or ball of fire. One of them weighed 20 lib., and made a hole in the ground in a perpendicular direction, driving up the earth to the height of eight or ten feet. It was taken out half an hour after, when it was still so hot that it could scarcely be held in the hand. The second formed a hole three feet deep, and weighed 40 lib. 1812, April 15: A stone, the size of a child's head, fell at Erxleben, and a specimen of it is in the possession of Professor Haussmann, of Brunswick. 1814, September 1: A few minutes before midday, while the sky was perfectly serene, a violent detonation was heard in the department of the Lot and Garonne. This was followed by three or four others, and finally by a rolling noise at first resembling a discharge of musketry, afterward the rumbling of carriages, and, lastly, that of a large building falling down. Stones were immediately afterward precipitated to the ground, some of which weighed 18 lib., and sunk into a compact soil to the depth of eight or nine inches, and one of them rebounded three or four feet from the ground. 1818, July 29, O. S.: A stone of 7 lib.

weight fell at the village of Slobodka, in Russia, and penetrated nearly sixteen inches into the ground. It had a brown crust with metallic spots. 1825, February 10: A meteoric stone, weighing 16 lib. 7 oz., fell from the air at Nanjemoy, Maryland. It was taken from the ground about half an hour after its fall, was sensibly warm, and had a sulphureous smell.

Several hundreds of instances similar to the above might be produced of large masses of stones having fallen from the upper regions upon the earth.* These stones, although they have not the smallest analogy with any of the mineral substances already known, either of a volcanic or any other nature, have a very peculiar and striking analogy with each other. They have been found at places very remote from each other, and at very distant periods. The mineralogists who have examined them agree that they have no resemblance to mineral substances, properly so called, nor have they been described by mineralogical authors. They have, in short, a peculiar aspect, and peculiar characters which belong to no native rocks or stones with which we are acquainted. They appear to have fallen from various points of the heavens, at all periods, in all seasons of the year, at all hours both of the day and night, in all countries in the world, on mountains and on plains, and in places the most remote from any volcano. The luminous meteor which generally precedes their fall is carried along in no fixed or invariable direction; and as their descent usually takes place in a calm and serene sky, and frequently in cloudless weather, their origin cannot be traced to the causes which operate in the production of rain, thunder-storms, or tornadoes.

From a consideration of these and many other circumstances, it appears highly probable, if not absolutely certain, that these substances proceed from regions far beyond the limits of our globe. That such solid substances, in large masses, could be generated in the higher regions of the atmosphere, is an opinion altogether untenable, and is now generally discarded, even by most of those philosophers who formerly gave it their support. That they have been projected from volcanoes is a hypothesis equally destitute of

* For more particular details on this subject, the reader may consult "The Edinburgh Encyclopædia," art. *Meteorite*. The "Edin. Phil. Journal," No. 2, p. 221-255. "Phil. Magazine," vol. xiii. "Retrospect of Philosophical Discoveries," 1805, vol. i., p. 201-210, &c., &c.

support; for the products of volcanoes are never found at any great distance from the scene of their formation, and the substances they throw out are altogether different in their aspect and composition from meteoric stones. Besides, these stones, in most instances, have descended to the earth in places removed hundreds, or even thousands of miles from any volcanic mountain, and at times when no remarkable eruption was known to take place. Perceiving no probability of their having their origin either in the earth or the atmosphere, Dr. Hutton, Poisson, La Place, and others, conjectured that they were projected from the moon. They demonstrated the abstract proposition, that a heavy body projected with a velocity of six thousand feet in a second may be carried beyond the sphere of the moon's attraction, and come within the attraction of the earth. But it has never yet been proved that volcanoes exist on the surface of the moon; and, although they did exist, and were as large and powerful as terrestrial volcanoes, they would have no force sufficient to carry large masses of stone with such a rapid velocity over a space of several thousands of miles. Besides, were the moon the source of meteoric stones, ejected from the craters of volcanoes, we should expect such volcanic productions to exhibit several varieties of aspect and composition, and not the precise number of ingredients which are always found in meteoric stones. From a consideration of the difficulties attending this hypothesis, La Place was afterward induced to change his opinion.

In order to trace the origin of meteoric stones, we are therefore under the necessity of directing our views to regions far beyond the orbit of the moon. On the supposition that the bursting of a large planet was the origin of the small planets Vesta, Juno, Ceres, and Pallas, we may trace a source whence meteoric stones probably originate. "When the cohesion of the planet was overcome by the action of the explosive force, a number of little fragments, detached along with the greater masses, would, on account of their smallness, be projected with very great velocity; and, being thrown beyond the attraction of the greater fragments, might fall towards the earth when Mars happened to be in the remote part of his orbit. When the portions which are thus detached arrive within the sphere of the earth's attraction, they may revolve round that body at different distances, and

may fall upon its surface, in consequence of a diminution of their centrifugal force; or, being struck by the electric fluid, they may be precipitated upon the earth, and exhibit all those phenomena which usually accompany the descent of meteoric stones." This opinion appears to have been first broached by Sir David Brewster, and is stated and illustrated in the "Edinburgh Encyclopædia," article *Astronomy*, and in vol. ii. of his edition of "Ferguson's Astronomy." Though not unattended with difficulties, it is perhaps the most plausible hypothesis which has yet been formed to account for the extraordinary phenomena of heavy substances falling with velocity upon the earth through the higher regions of the atmosphere.

On this subject I would consider it as premature to hazard any decisive opinions. I have laid the above facts before the reader that he may be enabled to exercise his own judgment and form his own conclusion. I have stated them particularly with this view, that they may afford a subject of investigation and reflection. For all the works and dispensations of the Almighty, both in the physical and moral world, are worthy of our contemplation and research, and may ultimately lead both to important discoveries and to moral instruction. Though "the ways of God" are, in many instances, "past finding out," yet it is our duty to investigate them so far as our knowledge and limited powers will permit. For as we are told, on the highest authority, that "the works of the Lord are great and marvellous," so it is declared that "they will be sought out" or investigated "by all those who have pleasure therein." There is, perhaps, no fact throughout the universe, however minute in itself, or however distant from the scene we occupy, but is calculated, when properly considered, to convey to the mind an impression of the character of the Deity and of the principles of his moral government. The mere philosopher may content himself with the application of the principles of chymistry and mathematics to the phenomena of matter and motion; and it is highly proper and necessary that both chymical and mathematical analysis be applied for the investigation of the laws and order of the material universe; but the man who recognises the principles of Divine Revelation will rise to still higher views. From nature he will ascend to nature's God, and trace the invisible perfections of the Eternal from the visible scene of his works;

and, from his physical operations, will endeavour to learn something of the order and economy of his *moral* administration.

If there be any foundation for the hypothesis to which we have adverted, it might be a question and a subject of consideration at what period the disruption of the supposed planet may have taken place. If the history of the fall of meteoric stones would be considered as throwing any light on this question, it will follow that such an event must have taken place at a very distant period; for the descent of such stones can be traced back to periods more than a thousand years before the commencement of the Christian era; perhaps even to the days of Joshua, when a shower of stones destroyed the enemies of Israel,* which would lead us to conclude that more than three thousand years must have elapsed since such an event. It might likewise be a subject of inquiry, why the Deity has exposed the earth to the impulse of such ethereal agents; for the fall of meteoric stones is evidently attended with imminent danger to the inhabitants of those places on which they fall. The velocity and impetus with which they descend are sufficient to cause instant death to those whom they happen to strike, and even to demolish human habitations, as happened in several of the instances above recorded. Would the Deity have permitted a world peopled with innocent beings to be subjected to such accidents and dangers? If not, is it not a presumptive proof that man, in being exposed to such casualties from celestial agents, as well as from storms, earthquakes, and volcanoes, is not in that state of primeval innocence in which he was created? And if we suppose that a moral revolution was the cause of the catastrophe which happened to the planet to which we allude, we may trace both a physical and a moral connexion, however distant, between the earth and that planet; for if the stones to which we allude are a part of the wreck of that world, they have been the means of exciting alarm among various tribes of the earth's population, and of

* These stones, in our translation of the Bible, are called *hailstones*, but without any reason, since the original word, *abenim*, signifies stones in general, according to the definition given in Parkhurst's Hebrew Lexicon; and in the book of Job, chap. xxviii., 3, the word is translated *stones of darkness;* meaning, undoubtedly, metallic stones or metals which are searched out from the bowels of the earth.

producing destruction and devastation; so that one depraved world has been the instrument in some degree of punishing another.

But perhaps I have gone too far in such speculations. I have stated them with the view of showing that we might occasionally connect our moral views of the Deity with the contemplation of the material fabric of the universe. When, through the medium of our telescopes and our physical investigations, we obtain a glimpse of the order and economy of a distant region of the universe, it may be considered as a new manifestation of the Deity, and it is our duty to deduce from it those instructions it is calculated to convey. And although we may occasionally deduce erroneous conclusions from existing facts, yet such speculations and reflections may sometimes have a tendency to excite an interesting train of thought, and to inspire us with an ardent desire of beholding the scene of the universe and the plan of the Divine administration more completely unfolded, in that world where the physical and moral impediments which now obstruct our intellectual vision shall be for ever removed.

VI. ON THE PLANET JUPITER.

Next to Pallas, in the order of the system, is the planet Jupiter. This planet, when nearest the earth, is the most splendid of all the nocturnal orbs, except Venus and the moon. Its distance from the sun is 495,000,000 of miles, and the circumference of its orbit, 3,110,000,000 of miles. Around this orbit it moves in eleven years and three hundred and fifteen days, at the rate of nearly thirty thousand miles every hour. When nearest to the earth, at the time of its opposition to the sun, it is about 400,000,000 of miles distant from us. A faint idea of this distance may be acquired by considering that a cannon-ball, flying five hundred miles every hour, would require more than ninety-one years to pass over this space; and a steam-carriage, moving at the rate of twenty miles an hour, would require nearly two thousand three hundred years before it could reach the orbit of Jupiter. When at its greatest distance from the earth, about the time of its conjunction with the sun, this planet is distant from us no less than 590,000,000 of miles; yet its apparent size, in this case, does not appear very much diminished, although it is 190,000,000 of miles farther from us in the latter case than in the former.

When viewed with a telescope, however, it appears sensibly larger and more splendid at the period of its opposition than when near the point of its conjunction.

Diurnal Rotation.—This planet has been found to revolve around its axis in the space of nine hours, fifty-nine minutes, and forty-nine and a half seconds. This discovery was made by observing a small spot in one of the belts, which appeared gradually to move across the disk of the planet. Mr. Hook appears to have first observed it in the year 1664; and in the following year, 1665, Cassini, that accurate observer of the heavens, perceived the same spot, which appeared round, and moved with the greatest velocity when in the middle, but was narrower and moved more slowly as it approached nearer the edge of the disk, which showed that the spot adhered to the body of Jupiter, and was carried round upon it. This spot continued visible during the following year, so that Cassini was enabled to determine the period of Jupiter's rotation to be nine hours and nearly fifty-six minutes. This rotation is far more rapid than that of any of the other planets, so far as we know, and nearly equals the velocity of Jupiter in his annual course round the sun. The circumference of this planet is 278,600 miles, and, therefore, its equatorial parts will move with a velocity of 28,000 miles an hour, which is 3000 miles more than the equatorial parts of the earth's surface move in twenty-four hours. This rapid velocity of the tropical regions of Jupiter, and of the places which lie adjacent to them, will have the effect of rendering all bodies *lighter* than they would be were the motion of rotation as slow as that of the earth. The gravity of bodies at the surface of Jupiter is more than twice as great as at the surface of the earth on account of his superior bulk; so that a body weighing one pound at the equatorial surface of the earth would weigh two pounds four ounces and a half at the surface of Jupiter. If, therefore, we were transported to the surface of that planet, we should be a burden to ourselves, being pressed down with more than double our present weight, and having but the same strength to support it. But Jupiter is *eleven* times larger in circumference than the earth; and hence, if both planets revolved on their axes in the same time, the centrifugal force on Jupiter would be eleven times greater than with us. But the squares of the number of revolutions performed in the same time by the earth and Jupiter; that is, the square of

twenty-four hours, and the square of nine hours, fifty-six minutes, are nearly as one to six; therefore, a body placed on Jupiter will have sixty-six* times a greater centrifugal force than with us, which would sensibly relieve the weight of the inhabitants if they stood in need of it. This rapid rotation would of itself relieve them of one eighth or one ninth of their whole weight; or, in other words, a body weighing eight stone at the equator of Jupiter, if the planet stood still, would gravitate with a force of only seven stone on the commencement of its diurnal rotation, at the rate at which we now find it.

It may perhaps be surmised by some that, since the semidiameter of Jupiter is eleven times greater than that of the earth, the attraction or weight of bodies on its surface ought to be eleven times greater than on the surface of our globe. This would be the case if the matter in Jupiter were as dense as in the earth; and the weight of bodies would, of course, be in proportion to their semidiameter, or the distance of the surface from the centres of these bodies. But the density of Jupiter is only a little more than that of water, while the density of the earth is five times greater. If the density of Jupiter were as great as that of the earth, and, consequently, the weight of bodies on its surface eleven times greater, men of our stature and make could scarcely be supposed to support eleven times the weight of such bodies as ours, but behooved to be almost chained down to the surface of the planet by their own gravity; and were we to suppose them of a larger stature, this inconvenience would become the greater; for the least of any species of animated beings have generally the greatest nimbleness and agility of motion. This circumstance is perhaps one of the reasons why the larger planets of the system have the least degree of density; for if Jupiter were composed of materials as dense as those of Mercury, organized beings like man would be unable, without a supernatural power, to traverse the surface of such a planet.

In consequence of the rapid motion of Jupiter, the days and nights will be proportionably short. The sun will appear to move through the whole celestial hemisphere, from the eastern to the western horizon, in less than five hours, and all the planets and constellations will appear to move with the same rapidity; so that the apparent motions of all these bod-

* That is $11 \times 6 = 66$.

ies will be perceptible to the eye when contemplating them only for a few moments, excepting those which appear near the polar regions. The sky of this planet will therefore assume an air of sublimity superior to ours, in consequence of all the bodies it contains appearing to sweep so rapidly around, and to change their positions in so short a space of time. As Jupiter moves round the sun in 4332 1-2 of our days, and round its axis in nine hours, fifty-six minutes, there will be 10,470 days in the year of that planet.

Magnitude and Superficial Contents of the Globe of Jupiter.—This planet is the largest in the system, being 89,000 miles in diameter, and, consequently, *fourteen hundred times* larger than the earth. Its surface contains 24,884,000,000, or twenty-four thousand eight hundred and eighty-four millions of square miles, which, at the rate of population formerly stated, 280 inhabitants to a square mile, would be sufficient for the accommodation of 6,967,520,000,000, or nearly *seven billions* of inhabitants, which is more than *eight thousand seven hundred times* the present population of our globe, and nearly *fifty* times the number of human beings that have existed on the earth since its creation. Although the one half of this planet were covered with water, which does not appear to be the case, it would still be ample enough to contain a population more than four thousand times larger than that of our globe. If such a population actually exist, as we have little reason to doubt, it may hold a rank, under the Divine government, equal to several thousands of worlds such as ours. Such an immense globe, replenished with such a number of intellectual beings, revolving with such amazing rapidity round its axis, moving forward in its annual course 30,000 miles every hour, and carrying along with it four moons larger than ours to adorn its firmament, presents to the imagination an idea at once wonderful and sublime, and displays a scene of wisdom and omnipotence worthy of the infinite perfections of its Creator.

Discoveries which have been made in relation to Jupiter by the Telescope.—Jupiter presents a splendid and interesting appearance when viewed with a powerful telescope. His surface appears much larger than the full moon to the naked eye; his disk is diversified with darkish stripes; his satellites appear sometimes in one position and sometimes in another, but generally in a straight line with each other. Sometimes

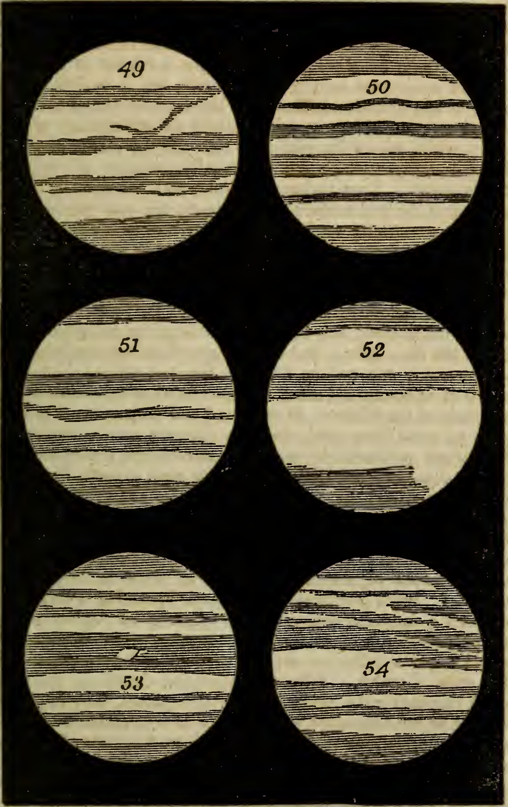
two of them are seen on one side of the planet and two on another; sometimes two only are visible, while the other two are eclipsed either by the disk or the shadow of Jupiter; and sometimes all the four may be seen on one side and in a straight line from the planet, in the order of their distances, so that these moons present a different aspect and relation to each other every successive evening.

These moons were first seen by Galileo, in the year 1610, by means of a telescope he had constructed, composed of two glasses, a concave next the eye and a convex next the object, which magnified about thirty-three times. No farther discoveries were made in relation to this planet till about the year 1633, when the *belts* were discovered by Fontana Rheita, Riccioli, and several others. They were afterward more particularly observed and delineated by Cassini. These belts appear like dark stripes across the disk of the planet, and are generally parallel to one another and to the planet's equator. They are somewhat variable, however, both as to their number and their distance from each other, and sometimes as to their position. On certain occasions *eight* have been seen at a time; at other times only one. Though they are generally parallel to one another, yet a piece of a belt has been seen in an oblique position to the rest, as in Fig. XLIX. They also vary in breadth; for one belt has been observed to have grown a good deal narrower than it was, when a neighbouring belt has been increased in breadth, as if the one, like a fluid, had flowed into the other. In favour of this opinion, it is stated in the "Memoirs of the Royal Academy of Sciences" that a part of an oblique belt was observed to lie so as to form a communication between them, as represented in Fig. XLIX. At one time, says Dr. Long, the belts have continued without sensible variation for nearly three months; at another time a new belt has been formed in an hour or two. They have sometimes been seen broken up and distributed over the whole face of the planet, in which state they are exhibited in some of the delineations of Sir W. Herschel; but this phenomenon is extremely rare, and does not appear to have been noticed by any other observer. In the year 1787 Schroeter saw two dark belts in the middle of Jupiter's disk; and near to them two white and luminous belts, resembling those which were seen by Campani in 1664. The equatorial zone which was comprehended between the two dark belts had assumed a dark

gray colour, bordering upon yellow. The northern dark belt then received a sudden increase of size, while the southern one became partly extinguished, and afterward increased into an uninterrupted belt. The luminous belts also suffered several changes, growing sometimes narrower, and sometimes one half larger than their original size.

The following figures represent some of the appearances of the belts of Jupiter.

Fig. XLIX. represents a view of Jupiter's belts by Cassini. Fig. L. a view from Dr. Hook, as delineated in the "Philosophical Transactions" for 1666, which was taken by a sixty feet refracting telescope. The small black spot on the middle belt, which did not appear at the beginning of the observation, and which moved about a third or fourth part across the disk in the space of ten minutes, was judged to be the shadow of one of the satellites moving across the disk of the planet. Fig. LI. exhibits a view of Jupiter as he appeared about the end of 1832 and beginning of 1833, which was taken by means of an achromatic telescope, with magnifying powers of 150 and 180 times. Fig. LII. is a view taken with the same telescope in 1837. In this view the principal belt near the planet's equator appeared dark, distinct, and well defined; but the other two belts at either pole were extremely faint, and could only be perceived after a minute inspection. Fig. LIII. is a view in which a bright and a dark spot were perceived on one of the belts; and Fig. LIV. a view by Sir John Herschel. I have had an opportunity of viewing Jupiter with good telescopes, both reflecting and achromatic, for twenty or thirty years past; and, among several hundreds of observations, I have never seen above four or five belts at one time. The most common appearance I have observed is that of two belts, distinctly marked, one on each side of the planet's equator, and one at each pole, generally broader, but much fainter than the others. I have never perceived much change in the form or position of the belts during the same season, but in successive years a slight degree of change has been perceptible, some of the belts having either disappeared, or turned much fainter than they were before, or shifted somewhat their relative positions; but I have never seen Jupiter without at least two or three belts. Some of the largest of these belts, being at least the one eighth part of the diameter of the planet in breadth, must occupy a space at least 11,000



miles broad and 278,000 miles in circumference ; for they run along the whole circumference of the planet, and appear of

the same shape during every period of its rotation. It is probable that the smallest belts we can distinctly perceive by our telescopes are not much less than a thousand miles in breadth.

What these belts really are has been a subject of speculation and conjecture among astronomers, but it is difficult to arrive at any definite conclusion. By some they have been regarded as immense strata of clouds in the atmosphere of Jupiter; while others imagine that they are the marks of great physical changes which are continually agitating the surface of this planet. I am inclined to think that the dark belts are portions of the real surface of the planet, and that the brighter parts are something analogous to clouds, or other substances with which we are unacquainted, floating in its atmosphere, at a considerable elevation above its surface. That the dark belts are the body of the planet appears highly probable from this consideration, that the spot by which the rotation of Jupiter was determined has been always found in connexion with one of the dark belts ; and as this spot must be considered as a permanent one on the body of Jupiter, so the belt with which it is connected must be considered as a portion of the real body of the planet. It is absurd and preposterous to suppose, as some have done, that the changes on the surface of Jupiter are produced by physical convulsions, occasioned by earthquakes and inundations ; for, in such a case, the globe of Jupiter would be unfit for being the peaceful abode of rational inhabitants. What should we think of a world where 5000 miles of ocean occasionally inundated a corresponding portion of the land, or where earthquakes sometimes swallowed up continents of several thousands of miles in length and breadth? Such physical catastrophes recurring every year on such a splendid and magnificent globe as Jupiter would not only render it unfit for the habitation of any beings, but would imply a reflection on the wisdom and benevolence of the great Creator. Whatever opinions, therefore, we may adopt respecting the phenomena of this planet, they ought to be such as are consistent with the idea of a habitable world and with the perfections of the Deity. Were the belts of Jupiter permanent and invariable, it would be comparatively easy to account for the phenomena which appear on his surface ; for the dark belts might be considered as seas, and the brighter portions of his surface as land. But as these belts, whether bright or dark, are found to be variable, we must have recourse

to another hypothesis for their explanation, or be content in the mean time to confess our ignorance. Our opinions and conjectures respecting the circumstances of other worlds are too frequently guided merely by what we know of the objects and operations which exist on our globe; and we are apt to think that the arrangements of other globes destined for the abode of intellectual beings must be similar to those of our own. We talk of physical convulsions, earthquakes, and inundations in Jupiter, and of volcanic eruptions in the sun and moon, as if these phenomena were as common in other worlds as in the earth; whereas it is not improbable that they are *peculiar* to our globe, and that they are connected with the moral, or rather *demoralized* state of its present inhabitants. There is an *infinite variety* in the system of nature; and it is highly probable that there is no world in the universe that exactly resembles another. Although Jupiter moves round the sun, and turns upon his axis by the same laws which direct the motions of our globe, yet there may be as great a difference in the arrangements connected with this planet and those of the earth, as there is between the constitution of the earth and that of a planet which revolves around the star Sirius. Would it be altogether improbable to suppose that the globe of Jupiter is partly enclosed within a sphere of semitransparent substance, at a considerable elevation above his surface, or rather within parallel rings, like an Armillary sphere composed of such a substance, which vary their position, and sometimes surround one part of his globe and sometimes another? These rings, of whatever substance they might be composed, might serve to reflect the rays of the sun so as to produce an addition of light and heat, and, at the same time, by exhibiting a variety of colours and motions, to diversify and adorn the firmament of this planet. Almost any supposition is preferable to the idea of a continued scene of physical convulsions. The idea now thrown out is not more extravagant than that of a planet nearly as large as Jupiter being surrounded with two concentric rings. Had we not discovered the rings of Saturn, we should never have formed the idea of a world environed with such an appendage. As a corroboration of the idea that the bright stripes which appear on this planet surround its body at a considerable elevation, it has been observed by Sir John Herschel, "that the dark belts do not come up in all their strength to the edge of the

disk, but fade away gradually before they reach it;" an almost decisive proof that the bright belts enclose the dark ones, or, in other words, the body of the planet; and that they are elevated above the dark globe of Jupiter, in all probability, not less than a thousand miles.

Whatever opinion we may form as to the constitution of this planet, the phenomena it presents afford a vast field for investigation and reflection. If it be a fact, as has been asserted by credible observers, that two belts have gradually disappeared during the time of an observation, and that, at another time, a new belt has been formed in an hour or two, agents far more powerful than any with which we are acquainted must have been in operation to produce such an effect, and changes more extensive than any which take place in our terrestrial sphere must have happened in the regions connected with Jupiter; for some of the belts of this planet are from five to ten thousand miles in breadth; and if those alluded to extended quite across the disk of the planet, they must have been more than one hundred and thirty thousand miles in length. Yet such a change may have taken place, not only without convulsions, causing terror and confusion, but to the admiration and joy of the inhabitants of that globe, as opening up a new and striking scene in the canopy of heaven; for if we suppose such bright belts or circles as we have imagined rapidly to shift their position in the canopy above, such a grand effect might in a short time be produced.

Besides the belts, spots of different kinds, some of them brighter and some darker than the belts, have been occasionally seen. The spot by which Jupiter's rotation was determined is the largest, and of the longest continuance of any hitherto observed. Its diameter is one tenth of the diameter of Jupiter, and it is situated in the northern part of the southern belt. Its centre, when nearest that of the planet, is distant from the centre of Jupiter about one third of the semidiameter of the planet. This spot was first perceived by Hook and Cassini in the years 1664, 1665, and 1666. It appeared and vanished eight times between the year 1665 and 1708. From 1708 till 1713 it was invisible; the longest time of its continuing to be visible was three years, and the longest period of its disappearing was from 1708 to 1713. It has evidently some connexion with the southern belt; for it has never been seen when that disappeared, though that belt has often been

visible without the spot. Besides this ancient spot, as it is called, Cassini, in the year 1699, saw one of less stability, which did not continue of the same shape and dimensions, but broke into several small ones, of which the revolution was but 9 hours, 51 minutes; and two other spots which revolved in 9 hours, 52½ minutes. The large spot described above, being about the one tenth of the diameter of Jupiter, must have been more than 8000 miles in extent, and, consequently, larger than the diameter of the earth. When Cassini had assured himself of the period of rotation from the motion of this spot, he made a report of his observations to the Royal Academy of Sciences, and calculated the precise moment when the spot would appear on the eastern limb of the planet, on a future day; on which the academy sent a deputation of M. Buot, M. Mariotte, and others, to be present at the observation; and when they came to the royal observatory, they saw the spot in the position predicted, and traced its motion for an hour or two, till the heavens began to be overcast with clouds. All the observations which have been made upon this spot and others, and its successive appearance and disappearance, perfectly agree with the idea of bright belts enclosing the globe of Jupiter at a distance from his surface, and varying their aspect and motions at different periods of time. And although some readers may consider it as a trifling matter to dwell with such particularity on a spot in Jupiter, yet that spot, however insignificant it may appear through our telescopes, may be more spacious and important in the system of nature than all the continents and islands of our globe, and may form a greater portion of the divine government than all the kingdoms of the earth.

There is a peculiar splendour in the appearance of Jupiter, both through the telescope and to the naked eye, considering his great distance from the sun and from the earth. The planet Mars appears comparatively dull and obscure, even when nearest the earth, when it is only fifty millions of miles distant; while the planet Jupiter, which is 350 millions of miles farther from the earth and from the source of light, presents a brilliancy of aspect far superior. This circumstance seems to indicate that there is some apparatus connected with the globe of Jupiter calculated to reflect the light of the sun in a peculiar manner, both on the surface of the planet itself, on its moons, and towards other planets. Such an apparatus

is not only consistent with the supposition thrown out above, but tends to corroborate it; and however strange we may consider the idea of brilliant belts surrounding a planet, yet as *variety* is stamped on all the works of the Creator, and as no world is precisely like another, the dissimilarity of such an appendage to what we know of our own or of other globes ought to be no argument against its existence. If we wish to know more of the phenomena of this planet than what we have hitherto ascertained, we must endeavour to improve our telescopes, and to increase, indefinitely, the number of observers. Were an immense number of intelligent observers distributed over different parts of the earth, and provided with the best telescopes; were they to mark with care and minuteness the phenomena to which we have adverted; were they to delineate, in a series of drawings, the various aspects of this planet during two or three periodical revolutions, marking the periods of the different changes, and the positions of the planet with respect to the earth and the sun, and noting at the same time the positions of the satellites when any change in the belts took place, we might possibly ascertain something more of the nature of the belts, whether dark or bright, of the periods of their changes, and whether these changes be influenced by the attractive power of the satellites. For if any appendage is connected with Jupiter composed of a substance of small density, it is reasonable to believe that its positions and movements would be affected at certain times by the positions of the satellites, especially when they all happened to be situated on the same side of Jupiter.

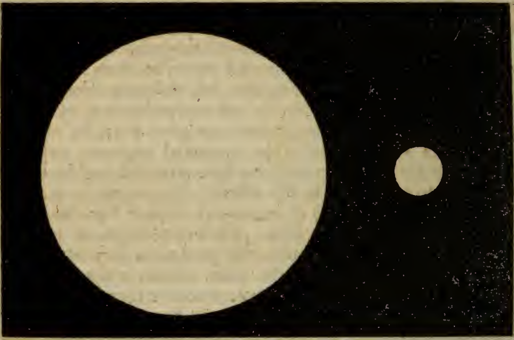
Seasons, Proportion of Light, &c. in Jupiter.—The axis of this planet being nearly perpendicular to the plane of its motion, there can be no variety of seasons similar to what we experience. The inclination of its axis, however, is stated by some astronomers to be 86 degrees, 54½ minutes, or 3 degrees, 5½ minutes from the perpendicular. This inclination will cause a slight variety of seasons at different periods of the planet's annual revolution, but not nearly to the same extent as in Mars or the earth. If the axis of Jupiter were as much inclined to his ecliptic as the axis of the earth, his polar regions would remain in darkness for nearly six years without intermission, just as the places around our north and south poles are deprived of the light of the sun for one half of the year. There will be nearly equal day and night in every part

of the surface of this planet; but to the places near the equator the sun will appear to rise to a high elevation above the horizon, and to move through the heavens with great rapidity, while near the polar regions he will appear to move comparatively slow, and to describe only a small semicircle above the horizon. We are not to imagine, however, that "everlasting winter" prevails around the poles of this planet, as some have asserted, because the sun never rises high above those regions, and the solar rays fall obliquely upon them; for there may be arrangements and compensations, of which we are ignorant, to produce nearly as great a degree of light and heat in the polar as in the equatorial regions; and perhaps the bright belts to which we have adverted may be so arranged as to contribute to this effect. Nor are we to imagine that there is no *variety of scenery* in Jupiter because there are no seasons similar to ours. For every degree of latitude from the equator to the poles will produce a diversity of aspect; and the variation of the belts, whatever may be their arrangement, and of what substances soever they may consist, will produce a diversity of scenery in the firmament of Jupiter far greater, and, perhaps, far more magnificent and transporting than anything we contemplate in our terrestrial abode.

The *intensity of the solar light* on the surface of Jupiter is twenty-seven times less than on the earth. The mean apparent diameter of the sun, as seen from the earth, is thirty-two minutes, three seconds; but the solar diameter, as seen from Jupiter, is only six minutes, nine seconds, which is less than one fifth so great as the sun appears to us. The square of 6′ 9″, or 369″, is 136161, and the square of 32′ 3″ is 369729, which, divided by 136161, produces a quotient of 27 1-6, which shows that the surface of the sun, as seen from Jupiter, is more than twenty-seven times less than he appears to us; and as the intensity of light decreases in proportion to the square of the distance, there will be twenty-seven times less light on this planet than on the earth. But if the intensity of the light be increased by reflection from any substances connected with this planet, or if the inhabitants have the pupils of their eyes much larger than ours, all the objects around them may appear with even greater splendour than on the earth. The following figures will show to the eye the proportional size of the sun as seen from Jupiter and from the earth. The small circle shows the comparative bulk of the solar orb as

seen from Jupiter, and the larger circle its bulk as viewed from the earth.

Fig. LV.



Nothing particular has been ascertained respecting an *atmosphere* surrounding this planet. Though it is probable that it has an appendage answering the purpose of an atmosphere, yet it may be very different in its nature and properties from that which surrounds the earth. And if the planet be surrounded with bright belts, as we have supposed, or if the bright parts of its surface are to be considered as something analogous to clouds suspended in a body of air, it is evident that the denser parts of its atmosphere never can be perceived by us, and that no dimness or obscurity is to be expected when a fixed star approaches its disk. Hence M. Schroeter, when he had a very clear and distinct view of the spots and belts when Jupiter suffered an occultation by the moon on the 7th April, 1792, could perceive nothing throughout the whole observation indicative of a refractive medium near the margin of the planet.

Jupiter is remarkable on account of his *spheroidal figure.* This figure is obvious to the eye when viewing the plane with a high magnifying power. Nor is this an optical illusion; for both diameters have been accurately measured by the mi-

crometer; and the equatorial diameter is found to be in proportion to the polar nearly as fourteen to thirteen, so that the equatorial is more than 6300 miles longer than the polar diameter. This oblate figure is ascribed to the swiftness of Jupiter's rotation, which produces a centrifugal force, which has a tendency to make the equatorial parts more protuberant than the polar. From calculations formed on the principles of physical astronomy, it is found that the proportion above stated is really the degree of oblateness which corresponds, on those principles, to the dimensions of this planet and the time of its rotation; so that theory perfectly harmonizes with observation.

The *density* of this planet compared with that of water is as 1 1-24 to 1; that is, it is a small fractional part denser than water. Its *mass*, compared with that of the sun, is as 1 to 1067; compared with that of the earth, as 312 to 1, that is, Jupiter could weigh 312 globes of the same size and density as the earth. The *eccentricity* of its orbit is 23,810,000 miles; and the *inclination* of the orbit to the ecliptic is about one degree, nineteen minutes. Its mean *apparent diameter* is thirty-eight seconds, and its greatest diameter, when in opposition to the sun, forty-seven and a half seconds. Its mean *arc of retrogradation* is nine degrees, fifty-four minutes, and its mean duration about 121 days. This retrogradation, or moving contrary to the order of the signs, commences or finishes when the planet is not more than 115 degrees from the sun. The following figure exhibits a view of Jupiter and his satellites as seen through a good telescope. (See *Fig. LVI.*)

VII. ON THE PLANET SATURN.

The planet Saturn may be considered in almost every respect as the most magnificent and interesting body within the limits of the planetary system. Viewed in connexion with its satellites and rings, it comprehends a greater quantity of surface than even the globe of Jupiter; and its majestic *rings* constitute the most singular and astonishing phenomena that have yet been discovered within the limits of our system.

Its distance from the sun is 906 millions of miles, which is nearly twice the distance of Jupiter; and the circumference of its orbit is 5,695,000,000 of miles; to move round which a cannon ball would require more than 1300 years, although

FIG. LVI.

it were moving 500 miles every hour. But a steam-carriage, moving at the rate of twenty miles an hour, would require above 32,500 years to complete the same round. When nearest the earth, Saturn is 811 millions of miles distant, an interval which could not be traversed by a carriage, at the rate now stated, in less than 4629 years; and even a cannon ball, moving with the velocity above mentioned, would require 184 years. So that, although man were divested of the gravitating power, and capable of supporting himself amid the ethereal regions, and though he were invested with a power of rapid motion superior to any movement we perceive on earth, before he could reach the middle orbit of the planetary system, or one fourth of its diameter, it would require a space of time far more than is yet allotted to mortal existence; and, therefore, all hope of personally exploring the celestial regions is completely annihilated, so long as we are invested with our present corporeal vehicles, and are connected with this terrestrial abode.

This planet revolves around the sun in the space of about 29 1-2 years, or in 10,758 days, 23 hours, 16 minutes, 34 seconds, which is its *siderial* revolution, or the time it takes in moving from a certain fixed star to the same star again. Through the whole of its circuit it moves at the rate 22,000

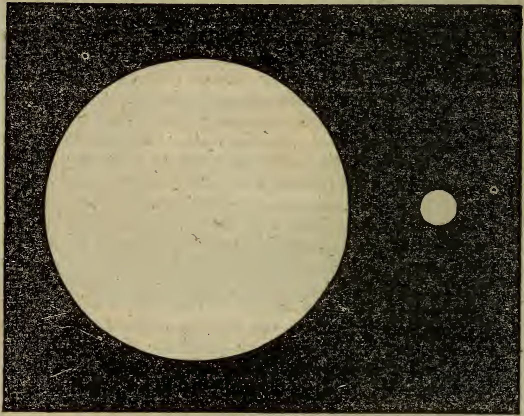
miles every hour. The period of its rotation was for a long time unknown. About a century ago, it was conjectured by some astronomers that it was accomplished in about ten or eleven hours. It was not, however, till Sir W. Herschel applied his powerful telescopes to Saturn that its rotation was accurately determined. By certain dark spots which he perceived on its disk, and by their change of position, he ascertained that the diurnal rotation is performed in ten hours, sixteen minutes, and nineteen seconds.* It is remarkable that La Place, from physical considerations, had calculated the rotation of Saturn to be nearly the same as above stated, before Herschel had determined it by direct observation. The rotation is performed on an axis perpendicular to the plane of the ring. The circumference of Saturn being 248,000 miles, the parts about the equator will move at the rate of 24,000 miles an hour. Its year will consist of 25,150 days, or periods of its diurnal rotation.

Proportion of Light on Saturn.—This planet being about 9 1-2 times farther from the sun than the earth, it will receive only the *one ninetieth* of the light which we receive ; for the square of 9 1-2 is equal to 90 1-4. This quantity of light, however, is equal to the light which would be reflected from a thousand full moons such as ours ; and there can be little doubt that the beings that reside in this planet have their organs of vision so constructed as to be perfectly adapted to the quantity of light they receive ; and, by such an adaptation, all the objects around them may appear as splendidly enlightened, and their colours as vivid as they do on the globe on which we live. The apparent diameter of the snn, as seen from Saturn, is three minutes, twenty-two seconds ; but his mean apparent diameter, as seen from the earth, is equal to thirty-two minutes, three seconds. This proportion of size in which the sun appears from the earth and from Saturn is represented in the following figure, in which the small circle represents the size of the sun as seen from Saturn.

Discoveries by the Telescope on the Body of Saturn.—The great distance of this planet from the earth prevents us from observing its surface so minutely as that of Jupiter. Certain dusky spots, however, have of late years been occasionally seen on its surface, when very powerful telescopes were ap-

* Sir John Herschel states the period of rotation to be ten hours, twenty-nine minutes, seventeen seconds.

Fig. LVII.



plied, and by the motion of these its diurnal rotation was determined. Belts somewhat similar to those of Jupiter have likewise been seen. Huygens, more than 150 years ago, states that he had perceived five belts on Saturn which were nearly parallel to the equator. Sir W. Herschel, in his numerous observations, also observed several belts, which, in general, were parallel with the ring. On the 11th of November, 1798, immediately south of the shadow of the ring upon Saturn, he perceived a bright, uniform, and broad belt, and close to it a broad or darker belt, divided by two narrow white streaks, so that he saw five belts, three of which were dark and two bright. The dark belt had a yellow tinge. These belts cover a larger zone of the disk of the planet than the belts of Jupiter occupy upon his surface. With a magnifying power of 200 times I have sometimes seen one darkish belt on the body of Saturn; but it was much fainter than those of Jupiter. It does not appear that these belts vary or shift their positions, as the belts of Jupiter are found to do; the

dark ones are much fainter than those of Jupiter, and, therefore, it is most probable that they are permanent portions of the globe of Saturn, which indicate a diversity of surface and configuration either of land or water, or of some other substances with which we are unacquainted. When this planet is viewed with a good telescope, it appears, like Jupiter, to be of a spheroidal figure, or somewhat approaching to it. The proportion of its polar to its equatorial diameter is as 32 to 35, or nearly as 11 to 12; so that the polar diameter is more than 6700 miles shorter than the equatorial, which is a greater difference than that of the two diameters of Jupiter. Saturn was generally considered, till lately, as a regular spheroid; but on the 12th of April, 1805, Sir W. Herschel was struck with a very singular appearance when viewing the planet. "The flattening of the poles did not seem to begin till near a very high latitude, so that the real figure of the planet resembled a square, or rather a parallelogram, with the four corners rounded off deeply, but not so much as to bring it to a spheroid." It is probable that the action of the ring or its attractive power is the cause of the great protuberance which is found about the equatorial regions of Saturn.

Magnitude and Extent of Surface on Saturn.—This planet is about 79,000 miles in diameter, and nearly a thousand times larger than the earth. Its surface contains more than 19,600,000,000 of square miles, and, consequently, at the rate of 280 inhabitants to a square mile, it would contain a population of 5,488,000,000,000, or about five billions and a half, which is six thousand eight hundred and sixty times the present number of inhabitants on our globe; so that this globe, which appears only like a dim speck on our nocturnal sky, may be considered as equal to six thousand worlds like ours; and since such a noble apparatus of rings and moons is provided for the accommodation and contemplation of intelligent beings, we cannot doubt that it is replenished with ten thousand times ten thousands of sensitive and rational inhabitants; and that the scenes and transactions connected with that distant world may far surpass in grandeur whatever has occurred on the theatre of our globe.

Density of Saturn.—The density of Saturn compared with that of the earth is nearly as one to nine; compared with that of water, it is less than one half; so that the mean density of this planet cannot be much more than the density of cork;

and, consequently, the globe of Saturn, were it placed in an immense ocean, would swim on the surface as a piece of cork or light wood swims in a basin of water. There is none of the planets, so far as we know, whose density is so small as that of Saturn, or less than the density of water. We are not to imagine, however, that the materials which compose the surface of Saturn are as light as cork, or similar suostances; for anything we know to the contrary, they may be as dense as the rocks and mould which compose the crust of our globe. We have only to suppose that the globe of Saturn is hollow, or merely filled with some elastic fluid, and that the solid parts of its exterior crust form a shell of a hundred or two hundred miles in thickness. It is true, indeed, that the density of our globe increases from its surface downward, perhaps even to the centre. But we have no reason to suppose that this is the case with all the other planets; on the contrary, it is most probable that it is exactly the reverse in the case of Saturn; for if the materials which compose that planet were to increase in density towards the centre, the substances on its surface would have little more density or solidity than that of a cloud suspended in the atmosphere. And we know that, in all the works of the Creator, *variety* is one grand characteristic of his plans, even where the same general objects are intended to be accomplished, and the same *general* laws are in operation.

From want of correct views on this subject, several foolish and erroneous notions have been entertained and circulated. In a late number of a popular and extensively circulated journal, when treating of "Planetary Arrangements," it is stated, that "while on Mercury a native of earth would scarcely be able to drag one foot after another for the strong power pulling him to the ground, he could, on the planet Saturn, leap sixty feet high as easily as he could here leap a yard." Now both these positions are quite erroneous; for although the density of Mercury is about double the density of the earth, and nearly that of lead, yet the bulk of the two planets is very different, the diameter of the earth being nearly 8000 miles, while that of Mercury is only 3200, and the force with which a body placed on their surfaces gravitates to them is in proportion to their *masses* divided by the *squares of their diameters*. If Mercury were as large as the earth, an inhabitant of our globe placed on the surface of that planet would

feel himself "pulled to the gronnd" as if he were placed on a similar ball of lead, and his weight, of course, would be increased; but, as matters now stand, the gravitation on Mercury is only a small fraction greater than on the surface of the earth; so that, in this respect, ' a native of earth," and particularly an inhabitant of Greenland, might walk with nearly as much ease on the planet Mercury as under our equator. The same considerations show the absurdity of what is stated in relation to Saturn; for that planet is ten times the diameter of the earth; and though its density is nearly as small as that of cork, yet its immense bulk renders the force of gravity at its surface somewhat greater than even on the earth, and almost as great as on the surface of Mercury. A body which weighs one pound on the surface of the earth would weigh one pound and four drachms if removed to the surface of Saturn; so that a person, instead of being able to "leap sixty feet high" from the surface of this planet, would be unable to leap quite so high as he can do on the earth. In short, there is not a planet in the solar system, with the exception of Jupiter, on which an inhabitant of the earth might not move about as easily, in respect to gravitating power, as he does on the terraqueous globe; and even on Jupiter he would experience little more than double the weight he now feels. On some of the other planets, such as Mars and Juno, he would feel somewhat lighter than he now does, but not nearly so much as would enable him to leap to such a height as above stated. On the same principle, which is taken for granted in the above quotation, we might suppose that a person would feel much lighter were he placed on the surface of the sun, because the density of that luminary is little more than the density of water; whereas, in consequence of his immense size, the gravitating power would be *twenty-seven* times greater than at the surface of our globe. For, according to the calculations of La Place, a body which, at the earth's equator, weighs one pound, if transported to the surface of the sun would weigh about twenty-seven and a half pounds; from which it follows, that there a heavy body would descend about four hundred and twenty-five feet in the first second of time; consequently, were a man who weighs two hundred pounds to be placed on the sun, he would be pressed down to its surface with a force equal to five thousand five hundred pounds, or nearly two tons and a half, which

would fix him to the surface without power of motion. So that whatever beings may inhabit that globe, it is not fitted for the residence of man in his present state of organization.

The *eccentricity* of Saturn's orbit is 49,000,000 of miles, which is about the 1-37 part of the diameter of the orbit. Its inclination to the ecliptic is 2° 29 1-2′. Its apparent diameter, as seen from the earth, is seventeen minutes, six seconds; and its mean daily motion, two minutes of a degree.

VIII. ON THE RINGS OF SATURN.

Besides the appearances above described, this planet is encircled with a double ring, one of the most astonishing phenomena which have yet been discovered in the heavens, and which, therefore, requires a separate and particular description.

The first individual who perceived a glimpse of Saturn's ring was Galileo, soon after the invention of the telescope. He thought he saw that planet appear like two smaller globes on each side of a larger globe; or, as he expressed it, that "Saturn was in the shape of an olive." In the year 1610 he published his discovery in a Latin sentence, the meaning of which was, that he had seen Saturn appear *with three bodies*. After viewing Saturn in this form for two years, he was surprised to see him become quite round without his adjoining globes, and to remain in this state for some time, and, after a considerable period, to appear again in his triple form as before. This deception was owing to the want of magnifying power in the telescope used by Galileo; for the first telescope constructed by this astronomer magnified the diameters of objects only three times; his second improved telescope magnified only eight times; and the best telescope which, at that time, he found himself capable of constructing, magnified little more than *thirty times;* and with this telescope he made most of his discoveries. But a telescope of this power is not sufficient to show the opening or dark space between the ring and Saturn on each side of the planet; and at the time when it appeared divested of its two appendages, the thin and dark edge of the ring must have been in a line between his eye and the body of Saturn, which phenomenon happens once every fifteen years. About forty years after this period the celebrated Huygens greatly improved

the art of grinding object glasses; and with a telescope of his own construction, twelve feet long, and afterward with another of twenty-three feet, which magnified objects one hundred times, he discovered the true shape of Saturn's ring, and in 1659 he published his "*Systema Saturnium*," in which he describes and delineates all its appearances.

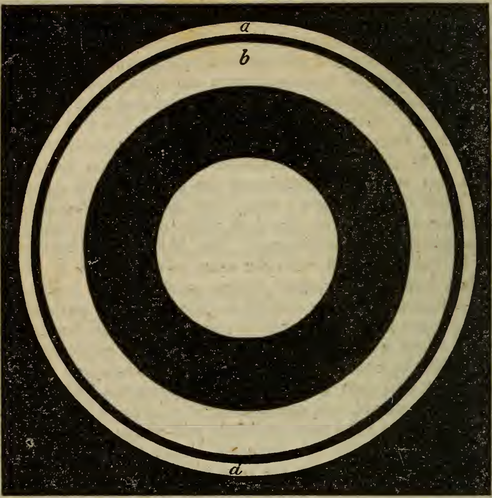
It was suspected by astronomers more than a century ago that the ring of Saturn was double, or divided into two concentric rings. Cassini supposed it probable that this was the case. Mr. Pound, in the account of his observations on Saturn in 1723, by means of Hadley's new reflecting telescope, states that with this instrument he could plainly perceive "*the black list in Saturn's ring*," and gives an engraving of the planet and ring with this dark stripe distinctly marked, as in the modern views of Saturn.* Mr. Hadley likewise states† that, in the year 1722, with the same telescope, he observed the dark line on the ring of Saturn parallel to its circumference, which was chiefly visible on the ansæ, or extremities of the elliptic figure in which the ring appears, but that he was several times able to trace it quite round; particularly in May, 1722, he could discern it without the northern limb of Saturn, in that part of the ring that appeared beyond the globe of the planet, and could perceive that the globe of Saturn reflects less light than the inner part of the ring. It was not, however, till Sir W. Herschel began to make observations on this planet with his powerful telescopes that Saturn was recognised as being invested with two concentric rings. The following cut (Fig. LVIII.) exhibits a view of Saturn and his rings, nearly in their respective proportions, as they would appear were they placed perpendicular to our line of sight; but, on account of the oblique angle they generally form to our line of vision, we never see them through the telescope in this position.

The following are the dimensions of the rings, as determined by the observations of Sir W. Herschel, which are here expressed in the nearest round numbers. Outside diameter of the *exterior* ring, *a d*, 204,800 miles, which is nearly twenty-six times the diameter of the earth. Inside di-

* See "*Philosophical Transactions*," No. 378, for July, 1723; and Reid and Gray's Abridgment, vol. vi., p. 153.

† "*Philosophical Transactions*," No. 378; or Abridgment, vol. vi., p. 154.

Fig. LVIII.



ameter of this ring, 190,200 miles ; breadth of the dark space between the two rings, 2839 miles, which is 700 miles more than the diameter of our moon, so that a body as large as the moon would have room to move between the rings. Outside diameter of the *interior* ring *b*, 184,400, and the inside diameter, 146,300 miles. *Breadth* of the exterior ring, 7200 miles ; breadth of the interior 20,000 miles, or 2½ times the diameter of the earth ; so that the interior ring is nearly three times broader than the exterior. The *thickness* of the rings has not yet been accurately determined. Sir John Herschel supposes that it does not exceed a hundred miles. "So very thin is the ring," says Sir John, "that it is quite invisible, when its edge is directly turned to the earth, to any but telescopes of extraordinary power." On the 19th of April, 1833,

" the disappearance of the rings was complete when observed with a reflector eighteen inches in aperture and twenty feet in focal length."* The breadth of the two rings, including the dark space between them, is very nearly equal to the dark space which intervenes between the globe of Saturn and the inside of the interior ring. It appears to have been lately ascertained that this double ring is not exactly circular, but eccentric. This seems to have been first observed by M. Schwalz, of Dessau, in 1828. He informed M. Harding of it, who thought he saw the same thing; M. Harding informed Professor Schumacher, who applied to M. Struve to settle the question by means of the superb micrometer attached to his great telescope. M. Struve measured the distance between the ring and the body of the planet on five different days, and ascertained that *Saturn's ring is really eccentric*, and, consequently, that the centre of the planet does not coincide with the centre of the ring; but that the centre of gravity of the rings oscillates round that of the body of Saturn, describing a very minute orbit. This is considered as of the utmost importance to the *stability* of the system of the rings, in preventing them from being shifted from their equilibrium by any external force, such as the attraction of the satellites, which might endanger their falling upon the planet. That this double ring really consists of two concentric rings, was demonstrated, says Professor Robinson, " by a star having been seen through the interval between them."

This double ring is now found to have a swift rotation around Saturn in its own plane, which it accomplishes in about ten hours and a half. This is very nearly the periodic time which a satellite would take in revolving at the same distance from the centre of Saturn. This rotation was detected by observing that some portions of the ring were a little less bright than others. Sir W. Herschel, when examining the plane of the ring with a powerful telescope, perceived near the extremity of its arms or *ansæ* several lucid or protuberant points, which seemed to adhere to the ring. At first he imagined them to be satellites, but afterward found, upon careful examination, that none of the satellites could ex

* Sir John Herschel states the dimensions of these rings on a somewhat lower scale than what his father had determined. He says that they were calculated from Professor Struve's micrometrical measures; but admits that some of the dimensions he states are perhaps too small.

hibit such an appearance, and therefore concluded that these points adhered to the ring, and that the variation in their position arose from a rotation of the ring round its axis in the period above stated. The circumference of the exterior ring being 643,650 miles, every point of its outer surface moves with a velocity of more than a thousand miles every minute, or seventeen miles during one beat of the clock. It is highly probable that this rapid rotation of the ring is one of the principal causes, under the arrangements of the Creator, of *sustaining* the ring, and preventing it from collapsing and falling down upon the planet. This double ring is evidently a *solid* compact substance, and not a mere cloud or shining fluid; for it casts a deep shadow upon different regions of the planet, which is plainly perceived by good telescopes. Besides, were it not a solid arch, its centrifugal force, caused by its rapid rotation, would soon dissipate all its parts, and scatter them in the surrounding spaces. It is not yet ascertained whether both the rings have the same period of rotation. This magnificent appendage to the globe of Saturn is about 30,000 miles distant from the surface of the planet, so that four globes nearly as large as the earth could be interposed between them; it keeps always the same positon with respect to the planet; is incessantly moving around it; and is carried along with the planet in its revolution round the sun.

The surface of the double ring does not seem to be exactly plane. One of the ansæ* sometimes disappears and presents its dark edge, while the other ansa continues to appear, and exhibits a part of its plane surface. On the 9th of October, 1714, the ansæ appeared twice as short as usual, and the eastern one much longer than the western. On the first of the same month, the largest ansa was on the east side; on the 12th, the largest ansa was on the west side of Saturn's disk;† which led the observers, even at that period, to conclude that the ring had a rotation round the planet. On the

* The parts of the ring about the ends of the longest axis, reaching beyond the disk of the planet, are called the *ansæ.* Ansa signifies a *handle*, which name was given when telescopes were so imperfect as to represent Saturn as a globe with two small knobs on each side. The same name is still continued, though it is somewhat improper, now that the true shape of this appendage is known. Still the general appearance of Saturn is somewhat like a globe, with an ansa or handle on each side.

† Memoirs of the Royal Academy of Sciences for 1715.

11th of January, 1774, M. Messier observed both the ansæ completely detached from the planet, and the eastern one larger than the other. In 1774, Sir W. Herschel likewise observed Saturn with a single ansa. From these observations, it has been concluded that there are irregularities on the surface of the ring, analogous, perhaps, to mountains and vales of vast extent; and that the occasional disappearance of the ansæ may possibly arise from a curvature in its surface. Sir W. Herschel was of opinion that the *edge* of the exterior ring is not flat, but of a spherical, or rather spheroidal form.

Dimensions of Saturn's Rings.—It is difficult for the mind to form an adequate conception of the magnitude, the mechanism, and the magnificence of these wonderful rings, which form one of the most astonishing objects that the universe displays. In order to appreciate, in some measure, the *immense size* of these rings, it may be proper to attend to the following statements: Suppose a person to travel round the outer edge of the exterior ring, and to continue his journey without intermission at the rate of twenty-five miles every day, it would require more than *seventy years* before he could finish his tour round this immense celestial arch. The interior boundary of the *inner* ring encloses a space which would be sufficient to contain within it three hundred and forty globes as large as the earth; and the *outer* ring could enclose within its inner circumference five hundred and seventy-five globes of the same magnitude, supposing every portion of the enclosed area to be filled. This outer ring would likewise enclose a globe containing 2,829,580,622,048,315, or more than two thousand eight hundred *billions* of cubical miles, which globe would be equal to more than *ten thousand eight hundred globes* of the size of the earth. In regard to the *quantity of surface* contained in these rings, the one side of the outer ring contains an area of 4,529,401,800, or more than four thousand five hundred millions of square miles. The one side of the inner ring contains 9,895,780,818, or nearly ten thousand millions of square miles. The two rings, therefore, contain on one side above fourteen thousand four hundred millions of square miles; and as the other sides of the rings contain the same extent of surface, the whole area comprehended in these rings will amount to 28,850,365,236, or more than twenty-eight thousand eight hundred millions of square miles. This quantity of surface is equal to 146 times

the number of square miles in the terraqueous globe, and is more than 588 times the area of all the habitable portions of the earth. Were we to suppose these rings inhabited (which is not at all improbable), they could accommodate a population, according to the rate formerly stated, of 8,078,102,266,080, or more than *eight billions*, which is equal to more than *ten thousand times* the present population of our globe; so that these rings, in reference to the space they contain, may be considered, in one point of view, as equal to ten thousand worlds.

Were we to take into consideration the *thickness* of the rings, we should find a very considerable addition to the area above stated. Supposing, according to Sir J. Herschel's estimate, that they are only one hundred miles thick, the area of the exterior circumference of the edge of the *outer* ring will be 64,365,700 miles; and that of the interior edge, 59,777,100. The exterior edge of the *inner* ring will contain an area of 57,954,200 square miles, and the interior edge 45,980,000; in all, 228,077,000 square miles, which is thirty-one millions of square miles more than the whole area of our globe.

These rings, therefore, exhibit a striking idea of the *power* of the Creator, and of the grandeur and magnificence of his plans and operations. They likewise display the depths of his *wisdom* and intelligence; for they are so adjusted, both in respect to their position around the body of the planet and to the degree of motion impressed upon them, as to prevent both their falling in on the planet and their flying off from it through the distant regions of space. We have already stated that the rings are not exactly concentric with the body of the planet. Now, it is demonstrable, from physical considerations, that were they mathematically perfect in their circular form, and exactly concentric with the planet, "they would form a system in a state of *unstable equilibrium*, which the slightest external power," such as the attraction of the satellites, "might completely subvert, by precipitating them unbroken on the surface of the planet." For physical laws must be considered as operating in the system of Saturn as well as in the earth and moon, and the other planets; and every minute circumstance must be adjusted so as to correspond with these laws. "The observed oscillation," says Sir J. Herschel, "of the centres of the rings about that of the planet is, in itself, the evidence of a perpetual contest between con-

servative and destructive powers, both extremely feeble, but so antagonizing one another as to prevent the latter from ever acquiring an uncontrollable ascendency and rushing to a catastrophe." "The smallest difference of velocity between the body and rings must infallibly precipitate the latter on the former, never more to separate ; consequently, either their motions in their common orbit round the sun must have been adjusted to each other by an external power with the minutest precision, or the rings must have been formed about the planet while subject to their common orbitual motion, and under the full free influence of all the acting forces." Here, then, we have an evident proof of the consummate wisdom of the almighty Contriver in so nicely adjusting everything in respect to number, weight, position, and motion, as to preserve in undeviating stability and permanency this wonderful system of Saturn ; and we have palpable evidence that everything conducive to this end has been accomplished, from the fact that no sensible deviation has been observed in this system for more than 220 years, or since the ring was discovered ; nor, in all probability, has there ever been any change or catastrophe in this respect since the planet was first created and launched into the depths of space.

Appearance of the Rings from the Body of Saturn.—These rings will appear in the firmament of Saturn like large luminous arches or semicircles of light, stretching across the heavens from the eastern to the western horizon, occupying the one fourth or one fifth part of the visible sky. As they appear more brilliant than the body of the planet, it is probable that they are composed of substances fitted for reflecting the solar light with peculiar splendour, and, therefore, will present a most magnificent and brilliant aspect in the firmament of Saturn. Their appearance will be different in different regions of the planet. At a little distance from the equator they will be seen nearly as complete semicircles, stretching along the whole celestial hemisphere, and appearing in their greatest splendour. In the daytime they will present a dim appearance, like a cloud or like our moon when the sun is above the horizon. After sunset their brightness will increase, as our moon increases in brilliancy as the sun disappears, and the shadow of the globe of Saturn will be seen on their eastern boundary directly opposite to the sun. This shadow will appear to move gradually along the rings till midnight, when it

will be seen near the zenith, or the highest point of these celestial arches. After midnight it will appear to decline to the western horizon, where it will be seen near the time of the rising of the sun. After sunrise the brightness decays, and it appears like a cloudy arch throughout the day. The following circumstances will add to the interest of this astonishing spectacle: 1. The *rapid motion* of the rings, which will appear to move from the eastern horizon to the zenith in two hours and a half. 2. The *diversity of surface* which the rings will exhibit; for if we can trace inequalities upon these rings by the telescope at the distance of more than 800,000,000 of miles, much more must the inhabitants of Saturn perceive all the variety with which they are adorned when they are placed so near them as the one eighth part of the distance of our moon. Every two or three minutes, therefore, a new portion of the scenery of the rings will make its appearance in the horizon with all their diversified objects; and if these rings be inhabited, the various scenes and operations connected with their population might be distinguished from the surface of Saturn with such eyes as ours, aided by our most powerful telescopes. 3. The motion of the shadow of the globe of Saturn in a direction contrary to the motion of the rings, which shadow will occupy a space of many thousand miles upon the rings, will form another variety of scenery in the firmament. 4. If the two rings revolve around the planet in different periods of time, the appearances in the celestial vault will be still more diversified; then one scene will be seen rising on the upper, and another and a different scene rising on the lower ring; and, through the opening between the rings, the stars, the planets, and one or two of the satellites may sometimes appear.

Near the polar regions of the planet only a comparatively small portion of the rings will appear above the horizon, dividing the celestial hemisphere into two unequal parts, and presenting the same general appearance now described, but upon a smaller scale. Towards the polar points the rings will, in all probability, be quite invisible. During the space of fourteen years and nine months, which is half the year of this planet, the sun shines on the one side of these rings without intermission, and during the same period he shines on the other side. During nearly fifteen years, therefore, the inhabitants on one side of the equator will be enlightened by

the sun in the daytime and the rings by night, while those on the other hemisphere, who live under the dark side of the ring, suffer a solar eclipse of fifteen years' continuance, during which they never see the sun. At the time when the sun ceases to shine on one side of the ring and is about to shine on the other, the rings will be invisible for a few days or weeks to all the inhabitants of Saturn.

At first view we might be apt to suppose that it must be a gloomy situation for those who live under the shadow of the rings during so long a period as fifteen years; but we are not acquainted with *all the circumstances* of their situation, or the numerous beneficent contrivances which may tend to cheer them during this period, and, therefore, are not warranted to conclude that such a situation is physically uncomfortable. We know that they enjoy the light of their moons without almost any interruption; sometimes two, sometimes four, and sometimes all their seven moons are shining in their hemisphere in one bright assemblage. Besides, during this period is the principal opportunity they enjoy of contemplating the starry firmament, and surveying the more distant regions of the universe, in which they may enjoy a pleasure equal, if not superior, to what is felt amid the splendour of the solar rays; and it is not improbable that multitudes may resort to these darker regions for the purpose of making celestial observations; for the bright shining of the rings during the continuance of night will, in all probability, prevent the numerous objects in the starry heavens from being distinguished. The very circumstances, then, which might, at first view, convey to our minds images of gloom and horror, may be parts of a system in which are displayed the most striking evidences of beneficent contrivance and design. It must be a striking scene when the sun is of a sudden altogether intercepted, without any apparent cause, not to return for fifteen years; and, on the other hand, when, at the end of this period, his light again bursts all at once upon the astonished beholders, closing up, as it were, the prospects of the firmament, and diffusing his splendour on every surrounding object; and both events may be attended with sentiments of admiration and emotions of delight. At certain times of the year of Saturn, and in certain latitudes from his equator, the sun will be eclipsed for a short time, every day at noon, by the upper part of the exterior ring according as he declines more or less

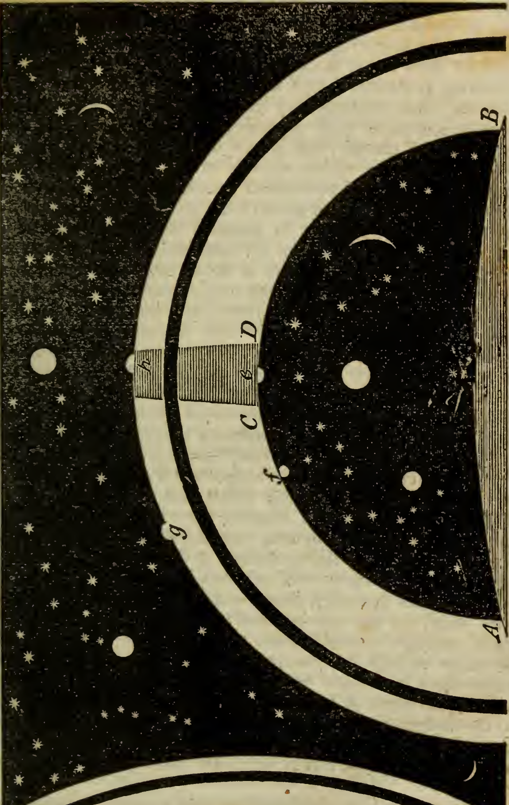
to the opposite side; and sometimes he will be partially eclipsed by the upper side of the exterior ring and the under side of the interior, and sometimes will be seen moving along the interval which separates these rings.

The opposite figures are intended to convey a rude idea of the objects connected with the firmament of Saturn.

Fig. LIX. represents the appearance of the rings at a little distance from the planet's equator, where they will appear nearly as complete semicircles. *A B* represents a portion of the globe of Saturn; *C D* the shadow of Saturn, as it appears upon the rings at midnight, after which it will appear to move gradually to the west till sunrise, when it will disappear below the horizon. The sun, partly eclipsed by the upper and lower edge of the rings in the daytime, is represented at *e*, *f*, *g*, and *h*. The other objects are some of the satellites in different phases, and the fixed stars, of which few will probably be seen, some of them within and some of them beyond the rings. Fig. LX. represents the rings as they will appear from places near the polar regions of the planet, from which situations they will appear as only small segments of circles near the horizon. The nearer the pole, the smaller the circles will appear.

From the above description, it appears that there is a great *variety* in the scenery presented in the firmament of Saturn; and this scenery is different as viewed from different regions of the planet. From the regions near the equator the rings will appear to the greatest advantage and in all their splendour. From these positions the various objects connected with the rings will be most distinctly observed, as the spectators will be at the nearest distance from the inner ring, which is about thirty thousand miles. At the latitude of 45° they will be twenty thousand miles farther from them; they will appear at a much lower elevation above the horizon, a smaller portion of their curve will be seen, and their *breadth* will occupy a less space in the heavens. At a higher latitude a still smaller portion will be seen, till they dwindle to a small curve or speck of light in the horizon; and at the poles they will be quite invisible by the interposition of the equatorial parts of the planet. Immediately under the equator the light of the rings will be scarcely visible, but the sun will occasionally illuminate the under edge of the interior ring, at *f*, *e*, *D*, and other places; which, at night, will appear like a narrow lu-

Fig. LIX.



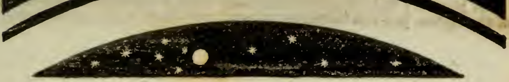


Fig. LX.

minous arch stretching directly across the zenith from the eastern to the western horizon, and diversified with the motion of the shadow of Saturn. Besides the different appearances of the starry regions, the various aspects of the moons, some of them rising, setting, and culminating,* some of them appearing as crescents, half moons, and full enlightened hemispheres, some entering into an eclipse, and some emerging from it, and all of them appearing to move with a rapid velocity around the sky, will greatly add to the *variety* and diversity of scenery which appears in the firmament of this planet. This diversity of aspect, which the scenery of nature presents from different regions of the planet, will, in all probability, have a tendency to promote frequent intercourses among the different tribes of its inhabitants, in order to contemplate the different scenes of nature and providence displayed throughout this spacious and magnificent globe. All these circumstances, properly considered, form of themselves a presumptive argument to prove that the sublime and exquisite contrivances connected with this planet were not intended merely to illuminate barren sands and hideous deserts, but to afford a comfortable and magnificent habitation for thousands of millions of rational inhabitants, who employ their faculties in the contemplation of the wonders which surround them, and give to their Creator the glory which is due to his name.

It has often been asked as a mysterious question, "What is the *use* of the rings with which Saturn is environed?" This is a question which I conceive there is no great difficulty in answering. The following considerations will go a great way in determining this question: 1. They are intended to produce all the varieties of celestial and terrestrial scenery which I have described above, and doubtless other varieties with which we are unacquainted; and this circumstance of itself, although we could devise no other reason, might be sufficient to warrant the Creator to deviate from his general arrangements in respect to the other planets. For *variety* is one characteristic of his plans and operations, both in respect to the objects on our globe and to those which exist throughout the planetary system, and it is accordant with those desires for novelty and variety which are implanted in the minds

* A heavenly body is said to *culminate* when it comes to the meridian, or the highest point of its diurnal course.

of intelligent beings. 2. They are intended to give a display of the *grandeur* of the Divine Being, and of the effects of his omnipotence. They are also intended to evince his inscrutable wisdom and intelligence in the nice adjustment of their motions and positions, so as to secure their stability and permanency in their revolutions, along with the planet, around the sun. 3. They are doubtless intended to teach us what varied scenes of sublimity and beauty the Deity has introduced or may yet introduce into various regions throughout the universe. We are acquainted with only a few particulars respecting *one* planetary system; but we have every reason to conclude that many millions of similar or analogous systems exist throughout the unlimited regions of space. In some of those systems the arrangements connected with the worlds which compose them may be as different from those of our globe and some of the other planets, as the arrangement and apparatus connected with Saturn are different from those of the planet Vesta or Mars. Around some of those worlds there may be thrown not only two concentric rings, but rings standing at right angles to each other, and enclosing and revolving round each other; yea, for aught we know, there may be an indefinite number of rings around some worlds, and variously inclined to each other, so that the planet may appear like a terrestrial globe suspended in the middle of an armillary sphere; and all those rings may be revolving within and around each other in various directions and in different periods of time, so as to produce a variety and sublimity of aspect of which we can form no adequate conception. There is nothing irrational or extravagant in these suppositions; for, had we never discovered the rings of Saturn, we could have formed no conception of such an appendage being thrown around any world, and it would have been considered in the highest degree improbable and romantic had any one broached the idea. We are therefore led to conclude, from the characteristics of *variety* impressed on the universe, that Saturn is not the only planet in creation that is surrounded with such an apparatus, and that the number and position of its rings are not the only models according to which the planetary arrangements in other systems may be constructed.

4. Besides the considerations now stated, the chief use, I presume, for which these rings were created was, *that they might serve as a spacious abode for myriads of intelligent*

creatures. If we admit that the globe of Saturn was formed for the reception of rational inhabitants, there appears no reason why we should not also admit that the rings were constructed chiefly for the same purpose. These rings, as we have already seen, contain a surface of about *thirty thousand millions* of square miles; and, if all the other planets be inhabited, it is not likely that the Creator would leave a space equal to nearly 600 times the habitable parts of our globe as a desolate waste, without any tribes of either sensitive or intelligent existence. It forms no objection to this idea that the rings are *flat*, and not globular like the planets; for the Creator can arrange any figure of a world into a suitable abode for intelligent beings; and on our globe we find myriads of animated beings fitted for every mode of existence, and in situations where we should scarcely ever have expected to see them. Besides, three or four centuries have scarcely elapsed since the earth was generally considered as a *plane* indefinitely extended; and the idea of its being a globe, inhabited on all sides, was scouted as untenable, and considered far more ridiculous than it can be now to suppose the flat rings of Saturn as serving the purpose of a habitable world. What should hinder them from serving this purpose as well as the globe of Saturn? They are *solid* arches, which is evident from their shadows and their rapid motion; they contain an ample space for an immense population; they have the power of attraction, like other material substances connected with the solar system; they are capable of being adorned with as great a diversity of surface, and as great a variety of beautiful and sublime objects, as this earth or any other of the planetary bodies; and it can make no great difference in the enjoyments of sentient and intellectual beings whether they live on a globe, a spheroid, a cylinder, or a plane surface, which the hand of Wisdom and Omnipotence has prepared for their reception; while it displays, at the same time, the variety of modes in which the Universal Parent can convey happiness to his numerous offspring. It may, perhaps, be objected to the idea of the habitability of these rings, that, while one side is enlightened during fifteen years without intermission, the other side remains in the dark during the same period. But the same thing happens with regard to extensive regions on the globe of Saturn; and, doubtless, arrangements are made for the enjoyment of the inhabitants in both cases

during this period. They enjoy in succession, and sometimes all at once, the light reflected from at least seven moons, and they behold occasionally the body of Saturn reflecting the solar rays from certain parts of its surface, and appearing like a vast luminous crescent, in different degrees of lustre, suspended in the sky. (See p. 197.)

Many other views and descriptions might be given of the phenomena connected with the system of Saturn, were it not that I do not wish to exhaust the patience of the reader by dwelling too long on one subject. The circumstance of two concentric rings being thrown around a planet, however simple it may at first sight appear, involves in it an immense variety of peculiar and striking phenomena, in regard both to the inhabitants of the planet and of the rings; so that it is difficult for the mind to form a precise and definite conception of every particular. To acquire even a general view of such phenomena, it would be requisite to construct a pretty large machine, representing the system of Saturn, in all its known motions and proportions, and to make it revolve around a central light. An instrument of this kind is as necessary for illustrating the subject on which we have been descanting, as an orrery or planetarium to illustrate the seasons and the planetary motions.

Telescopic Views of Saturn and its Rings.—As these rings present a variety of aspects as seen from different parts of the planet, so they appear to assume a different appearance at different times when viewed through our telescopes. Sometimes the planet appears to be completely divested of its rings; sometimes they appear only like a short luminous line or streak on each side of its body; sometimes they appear like handles on each side of the planet; and at other times like a large ellipse or oval almost surrounding the body of the planet. These varied aspects of the rings are owing to the following circumstances. The rings never stand at right angles to our line of vision; otherwise we should see them as represented in Fig. LVIII. (p. 190.) Our eye is never elevated more than thirty degrees above the plane of the rings. The *plane* of these rings preserves a position parallel to itself in every part of the planet's revolution, being constantly inclined at the same, or nearly the same angle to the orbit and to the ecliptic, which angle is about twenty-nine or thirty degrees. The *nodes of the rings* lie in 190°

and 350° of longitude, which correspond to the twentieth degree of Virgo and the twentieth of Pisces. When, therefore, the planet is in these points, the rings entirely disappear, because the thin edge of the outer ring only is turned towards our eye, and every trace of it is lost for some time, except the shadow of it, which appears like a dark belt across the planet. This disappearance happens once every fifteen years, but frequently with different circumstances. Two disappearances and two reappearances may occur in the same year, but never more. When Saturn is in the longitude above stated, the plane of the rings passes through the sun, and, the light then falling upon it edgewise, it is to us no longer visible. The rings likewise disappear when their plane passes through the earth; for its edge being then directed to the eye, and being too fine to be seen, the planet appears quite round and unaccompanied with its rings. When the earth is placed on the side of the rings, which is turned from the sun, we have a third cause of its disappearance. As the planet passes from the ascending to the descending node of the rings, the *northern* side of their plane is turned towards the sun. As it passes from the descending to the ascending node, the *southern* side of the rings is enlightened. In proportion as it recedes from these nodes, the rings appear to widen and to present a broader ellipsis, till it arrives at 90° from either node, or in 80° or 260° of longitude, corresponding to 20° of Gemini and 20° of Scorpio; at which time the rings will be seen to the greatest advantage, and appear almost surrounding the globe of Saturn. At the time of the greatest opening of the rings, their shorter diameter appears exactly one half of the longer diameter.

The following figures represent the different appearances of the rings during half the period of the revolution of Saturn, as seen through good telescopes. Fig. LX. shows the appearance of Saturn when the plane of the ring is parallel to the line of vision, and its thin edge turned to the eye. In this manner the planet appeared during the months of October, November, and part of December, 1832, when nothing was perceptible except the dark shade across its disk, as represented in the figure. The first time the weather permitted observations on Saturn about this period was December 27, when I perceived the ring, with a power of 180, appearing like a fine thread of light on each side of the planet, as represented

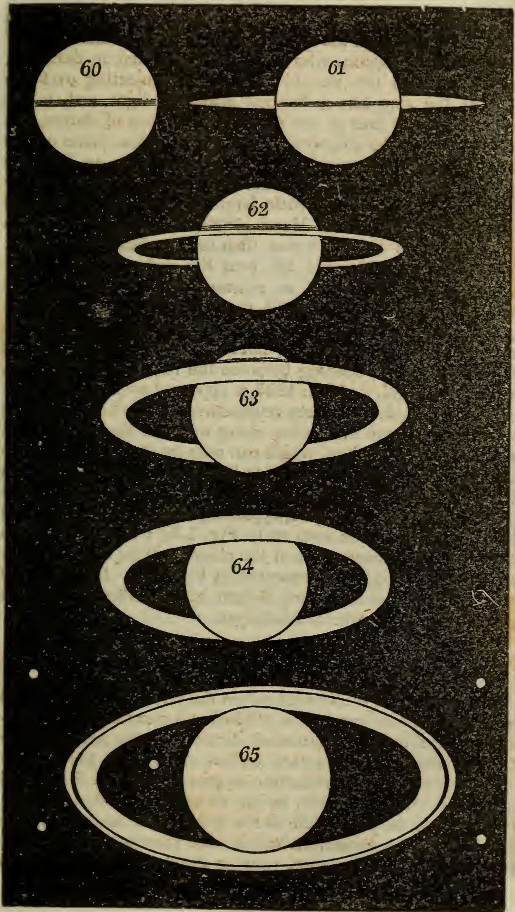

60
61
62
63
64
65

Fig. LXI. About the beginning of October the plane of the ring passed through the centre of the sun. At that time the inhabitants of Saturn, who had previously been in darkness, would perceive the margin of the sun projecting over the edge of the ring like a brilliant streak of light, and, in the course of about four of our days, or nine days of Saturn, the whole body of the sun would appear above the plane of the ring, gradually rising a little higher every day, as he does after the 21st March to the north pole of the earth. The ring began to appear a little larger during the months of January, February, and March, 1833; but in April it again disappeared, as the earth was then in the plane of the ring, and it continued invisible till near the end of June. After which it again appeared, as represented in Fig. LXI., and will now continue visible till the year 1847, when it will again disappear. In about a year after its second disappearance it appeared as in Fig. LXII. In about a year and a half afterward the opening between the rings appeared wider, as in Fig. LXIII.; and in 1837 it appeared as in Fig. LXIV. In Fig. LXV. the rings are represented at the utmost extent in which they are ever seen, along with the dark space that separates the two rings, which can only be distinguished by a telescope magnifying from 220 to 300 times. In this position it will be seen in 1840; after which it will pass through all the gradations here represented, appearing narrower every year till 1847, when it will be seen as in Fig. LXI; soon after which it will entirely disappear, and the planet will be seen as if divested of its ring, as represented in Fig. LX. Such are the various aspects under which Saturn and its rings appear, as viewed through powerful telescopes.

IX. ON THE PLANET URANUS.

Since the time of Newton, when the physical causes of the celestial motions began to be studied and investigated, astronomers have had their attention directed to the power or influence which the planetary bodies exert upon each other This power is termed attraction or gravitation, and is inherent in all material substances, so far as our knowledge extends. It is exerted in proportion to the quantity of matter and the distances of the respective bodies; the planets, in their nearest approach to each other, causing some slight deviations in

their orbits and motions. Some disturbances or inequalities in the motions of Jupiter and Saturn, which could not be accounted for from the mutual action of these planets, led certain astronomers to conclude that another planet of considerable magnitude existed beyond the orbit of Saturn, by the action of which these irregularities were produced. It was not, however. till near the close of the eighteenth century that this happy conjecture was realized and confirmed. To the late Sir W. Herschel astronomy is indebted for discovering a new primary planet, which had been previously unknown to all astronomers.

This illustrious astronomer, when residing in Bath, had constructed reflecting telescopes of a larger size and with higher powers than any that had been previously in use, and had devoted his unwearied attention to celestial observations. While pursuing a design which he had formed, of making minute observations on every region of the heavens, on the 13th of March, 1781, while examining, with one of his best telescopes, the constellation of Gemini, he observed a star near the foot of Castor, the light of which appeared to differ considerably from that of the neighbouring stars, or those which he found described in catalogues. On applying a higher magnifying power it appeared evidently to increase in diameter; and two days afterward he perceived that its place was changed, and that it had moved a little from its former position. From these circumstances he concluded that it was a comet, and sent an account of it as such to the astronomer royal. As a comet, however, it seemed particularly singular that no tail or nebulous appearance could be perceived; on the contrary, it was found to show with a faint steady light, somewhat paler than that of Jupiter. The account of this discovery soon spread throughout Europe, and was confirmed by observations made at Paris, Vienna, Milan, Pisa, Berlin, and Stockholm. The star was for some time generally considered as an extraordinary comet, free of all nebulosity, and astronomers were occupied in determining the parabolic elements of its course. "The President Bochard de Saron, of the Academy of Sciences of Paris, and Lexel, an astronomer of St. Petersburg, who was in London at the time, were the first who discovered its circular form, and calculated the dimensions of its orbit. It was no longer doubted that Herschel's star was a new planet; and all subsequent observations

verified this unexpected result."* We have here a striking proof of the perfection of modern theories; for the laws regulating the motion of this new planet were determined before it had accomplished the twentieth part of its course, and that motion was not less accurately known than that of other planets which had been observed during so many centuries. Since its discovery to the present time, it has not yet moved much more than two thirds of a revolution round the sun; and yet its motions are calculated, and its place in the heavens predicted, with as much accuracy and certainty as those of the other planets, a circumstance which demonstrates the precision of modern astronomers, and which should lead the unskilful in astronomy to rely on the deductions of this science, however far they may transcend their previous conceptions.

When the motion of this new planet was calculated, the points of the heavens which it had successively occupied during the preceding century could be pointed out; and it occurred to some astronomers that it might possibly have been observed before, though not known to be a planet. Mr. Bode, of Berlin, who had just published a work containing all the catalogues of zodiacal stars which had appeared, was induced to consult these catalogues in order to discover whether any star marked by one astronomer, and omitted by another, might not be the new planet in question. In the course of this inquiry he found that the star No. 964 in Mayer's catalogue had been unobserved by others, and observed only once by Mayer himself, so that no motion could have been perceived by him. On this Mr. Bode immediately directed his telescope to that part of the heavens where he might expect to find it, but without success. At the same time he found, by calculation, that its apparent place in the year 1756 ought to have been that of Mayer's star, and this was one of the years in which he was busied in his observations; and, on farther inquiry, it was found that the star 964 had been discovered by Mayer on the 15th of September, 1756; so that it is now believed that this star was the new planet of Herschel. It appears likewise that this star was seen several times by Flamstead, the astronomer royal, in the year 1690; once by Bradley; and eleven times by Lemonnier; all of whom con-

* Biographical Memoir of Sir. W. Herschel, by Baron Fourier. Read to the Royal Academy of Sciences, June 7, 1824.

sidered it as one of the fixed stars, but never suspected that it was a planetary body. The discovery of this planet enlarges our views of the extent of the solar system, and of the quantity of matter it contains, far more than if planets equal to Mercury, Venus, the Earth, the Moon, Mars, Vesta, Juno, Ceres, and Pallas, were to be added to that system; for, although it is scarcely distinguishable by the naked eye on the vault of heaven, it is more than twenty times larger than all these bodies taken together.

After this body was ascertained to belong to the planetary system, it became a subject of consideration by what name it should be distinguished. The old planets were distinguished by names borrowed from the heathen deities, a nomenclature which, perhaps, it might now be expedient to change; but Galileo and Cassini gave to the celestial bodies they discovered the names of the princes who had patronized their labours. Hence Galileo, when he had discovered the satellites of Jupiter, sent his drawings of them to his patron, Cosmo Medici, Great Duke of Tuscany, in honour of whom he called them *Medicean stars;* and Cassini named the satellites of Saturn which he discovered after Louis XIV. In imitation of these discoveries, Sir W. Herschel named his newly-discovered planet *Georgium Sidus*, in honour of his patron George the Third. But foreign astronomers, for a considerable time, gave it the name of *Herschel*, in honour of the discoverer; but afterward hesitated between the names Cybele, Neptune, and *Uranus*. This last name, derived from one of the Nine Muses who presided over astronomy, ultimately prevailed, and will probably distinguish this planet in future generations, unless the present nomenclature of the planets be abolished.

Distance and Period of Uranus.—Uranus is the most distant planet of the solar system, so far as our knowledge yet extends; although it is by no means improbable that planets may exist even beyond its orbit, distant as it is; for comets pass far beyond the limits of this planet, and again return to the vicinity of the sun. Its distance from the sun, in round numbers, is 1,800,000,000; that is, eighteen hundred millions of miles, which is double the distance of the planet Saturn. When nearest the earth, it is distant from us about 1,705,000,000 of miles. In order to acquire a rude conception of this distance, let us suppose a steam-carriage to set out from the earth, and to move, without intermission, twenty

miles every hour, it would require more than nine thousand, seven hundred and thirty years before it could reach the planet Uranus; so that, although the journey had been commenced at the creation of our globe, it would still require more than three thousand seven hundred years to arrive at its termination. Even a cannon ball, flying at the rate of twelve thousand miles every day, would require three hundred and eighty-nine years to reach the nearest point of the orbit of this planet. Yet the comet which appeared in 1835, in all probability, pursues its course far beyond the orbit of Uranus, and will, doubtless, visit this part of our system again, as it has done before, within the space of seventy-six years, although it must move more than double the above distance before it returns. The *circumference* of the orbit in which Uranus revolves about the sun is 11,314,000,000 of miles, through which it moves in 30,686 mean solar days, or about eighty-four years. It is the slowest-moving planet in the system, and yet it pursues its course at the rate of 15,000 miles every hour. Were a steam-carriage to move round the immense orbit of this planet at the rate above stated, it would require no less than sixty-four thousand, five hundred and seventy years before this ample circuit could be completed; and yet a globe eighty times larger than the earth finishes this vast tour in eighty-four years! This planet doubtless revolves round its axis as the other planets do, but the period of its rotation is as yet unknown. Its great distance from the earth prevents us from observing any spots or changes on its surface by which its rotation might be determined. La Place concludes, from physical considerations that it revolves about an axis very little inclined to the ecliptic; and that the time of its diurnal rotation cannot be much less than that of Jupiter or Saturn.

Magnitude and Dimensions of Uranus.—This planet is about 35,000 miles in diameter, and 110,000 miles in circumference, being about eighty-one times larger than the earth, and four thousands times larger than the moon. Its surface contains 3,848,460,000 of square miles, which is nineteen times the area of our globe, and seventy-eight times the area of all the habitable portions of the earth. At the rate of population formerly stated, 280 to a square mile, it could, therefore, accommodate 1,077,568,800,000, or more than one billion of inhabitants, which is one thousand three hundred and forty-seven times the population of our globe.

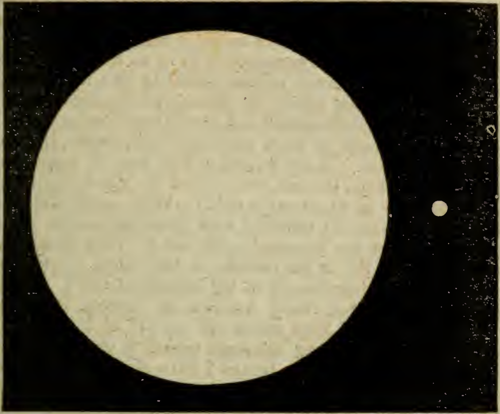
So that this planet, which escaped the notice of astronomers for more than five thousand years, forms a very considerable portion of the solar system and of the scene of the Divine government.

Proportion of Light on Uranus.—As this planet is nineteen times farther from the sun than the earth is, and as the square of 19 is 361, the intensity of light on its surface will be three hundred and sixty times *less* than what we enjoy. Yet this quantity of light is equal to what we should have from the combined effulgence of three hundred and forty-eight full moons; and, with a slight modification of our visual organs, such a proportion of light would be quite sufficient for all the purposes of vision. Though the light of the sun flies eighteen hundred millions of miles before it reaches this planet, and returns again by reflection nearly the same distance before it reaches the earth, yet it is distinctly visible through our telescopes, and sometimes even to the naked eye; and Uranus, with a moderate magnifying power, *appears* about as bright as Saturn. How small a quantity of solar light may suffice for the purpose of vision will be obvious by attending to the following circumstance: In the late solar eclipse which happened on the 15th of May, 1836, little more than the one twelfth part of the sun was visible at those places where the eclipse was annular. Almost every person imagined that a dismal gloom and darkness would ensue, yet the diminution of light appeared no greater than what frequently happens in a cloudy day. At the time of the greatest obscuration there was more than half the light which falls upon Uranus, and all the objects of the surrounding landscape, though somewhat deficient in brilliancy, were distinctly perceived. There can be no doubt that the organs of vision of the inhabitants of the different planets, being formed by Divine Wisdom, are exactly adapted to the objects amid which they are placed, and the quantity of light reflected from them; and there may be innumerable modes, unknown to us, by which this end may be effected. We can easily conceive, that if the pupils of our eyes were rendered capable of a greater degree of expansion than they now possess, or were the *retina*, on which the images of objects are depicted, endowed with a greater degree of nervous sensibility, so as to be more easily affected by the impulses of light, we might perceive as much splendour on all the objects connected with

Uranus, were we placed on that planet, as we now do on the scenery around us during the brightest days of summer. When we pass from the light of the sun into a darksome apartment, on our first entrance we can scarcely distinguish any object with distinctness; but after remaining five or six minutes, till the pupil has time to expand, every object around us is readily perceived; and, from the same cause, nocturnal animals can pursue their course with ease and certainty amid the deepest shades of night; so that the inhabitants of the most distant planet of our system, although it were removed from the sun to double the distance of Uranus, might perceive objects with all the distinctness requisite for the purposes of vision; and if the pupils of the eyes of such beings be much more expansive than ours (as is probably the case), it is highly probable they will be enabled to penetrate much farther into the celestial regions, and to perceive the objects in the firmament with much greater distinctness and "space-penetrating power" than we can do, even with the aid of instruments. It is likewise probable that the objects on the surface of the more distant planets of our system are fitted to reflect the rays of light with peculiar brilliancy. Hence we find that the light of Uranus, though descending upon us from a region 900 millions of miles farther than Saturn, appears as vivid as the light which is reflected to us from that planet. The apparent diameter of the sun, as seen from Uranus, is only 1 minute, 38 seconds; whereas his mean apparent diameter as seen from the earth is 32 minutes, 3 seconds; consequently this orb, as viewed from this planet, will appear very little larger than Venus appears to us in her greatest brilliancy, or Jupiter when near his opposition. The opposite figure represents to the eye the apparent size of the sun as seen from Uranus and from the earth, the small circle representing his size as seen from Uranus.

Temperature of Uranus.—If heat followed the same law as the propagation of light, and decreased as the square of the distance of the planet from the sun increased, then the surface of the planet Uranus would be a cold region indeed, in which no life or animation, such as we see around us, could exist. Baron Fourier, in his "Memoir of Herschel," says, "Its temperature is more than forty degrees below that of ice;" and if the degrees of Reaumur's thermometer be meant, this temperature will correspond to one hundred and

FIG. LXVI.



twenty-two degrees below the freezing point of Fahrenheit; a cold-enough region, truly. In accordance with such representations, the poets of the last century expatiated on the cold temperature of *Saturn* in such strains as the following:

> "When the keen north with all its fury blows,
> Congeals the floods, and forms the fleecy snows,
> 'Tis heat intense to what can there be known;
> Warmer our poles than is its burning zone.
> Who there inhabit must have other powers,
> Juices, and veins, and sense, and life, than ours.
> One moment's cold, like theirs, would pierce the bone,
> Freeze the heart's blood, and turn us all to stone."
>
> BAKER'S *Universe.*

This, it must be admitted, is *a very cold* poetic strain, almost sufficient to make one shiver, and to freeze our very thoughts; and if such a description were applicable to Saturn, it is much more so to the planet Uranus, at double the distance. But I presume it is more in accordance with poetic license than with the deductions of sound philosophy. We

have no valid reason to conclude that the degree of heat on the surfaces of the different planets is inversely proportional to the squares of their respective distances from the sun. The sun is to be considered chiefly as the great storehouse of *light*, and it may likewise be viewed as the great agent in the production of heat, without supposing it to be an enormous mass of fire, which the common opinion seems to take for granted. Its rays produce heat chiefly by exciting an insensible action between *caloric* and the particles of matter contained in bodies; and caloric appears to be a substance universally diffused throughout nature. If the degree of heat were in proportion to the distance from the sun, why should the upper regions of the atmosphere be so intensely cold? Why should the tops of lofty mountains be crowned with perpetual snows, while the plains below are scorched with heat? Why should an intense cold be felt in the latitude of 40°, when a comparative mildness is experienced in the latitude of 56°? In the state of Connecticut, North America, in January, 1835, the thermometer ranged from *minus* 25° to 27° of Fahrenheit; while in Scotland, during the same period, it was seldom so low as the freezing point. But as I have already thrown out some remarks on this subject when describing the planet Mercury, I need not enlarge (see page 70). In order to form correct ideas of the distribution of heat among the planetary bodies, we have only to suppose that the Creator has proportioned the quantity of caloric (or that which produces sensible heat) to the distance at which every planet is placed from the sun, so that a large quantity exists in Saturn and a smaller quantity in Mercury. If, therefore, the quantity of caloric connected with Uranus be in proportion to its distance from the sun, there may be as much warmth experienced in that distant region of the solar system as in the mildest parts of our temperate zones. So that we are under no necessity of associating the frigid and gloomy ideas of the poet with our contemplations of this expansive globe. At all events, we may rest assured that the Creator, whose wisdom is infinite in its resources, and whose "tender mercies are over all his works," has adapted the structure and constitution of the inhabitants of every planet to the nature and circumstances of the habitation provided for them, so as to render every portion of his dominions a comfortable abode for his intelligent offspring; provided they do not frustrate his benevolent designs (as has

been done in our world) by their rebellion and immoral conduct. For in no region of the universe, whatever may be its physical arrangements, can true happiness be enjoyed, unless love to God and love to all surrounding intelligences form the grand principles of action, and be uniformly displayed in every intercourse and association, and amid all the ramifications of moral conduct. On this basis chiefly rests the happiness of the intelligent universe ; and, wherever principles directly opposite to these prevail among any order of intellectual beings, whatever may be the structure or scenery of their habitation, misery and moral disorder must be the inevitable consequence.

The following additional particulars may be stated in relation to this planet: Its *density* is reckoned to be nearly equal to that of water. A body weighing one pound on the earth's surface would weigh only fourteen ounces, fourteen drachms, if removed to Uranus. The *eccentricity* of its orbit is 85,000,000 of miles, which is about the 1-42 part of its diameter. Its mean *apparent diameter*, as seen from the earth, is about four seconds. The *inclination of its orbit* to the ecliptic is forty-six minutes, twenty-six seconds, so that it is never much more than three fourths of a degree from the ecliptic. This inclination is less than that of any of the other planetary orbits. Six satellites are supposed to be connected with Uranus, but their periods and other phenomena have not yet been accurately ascertained.

In the preceding pages I have given a brief sketch of the principal phenomena connected with the *primary* planets of our system. Whether any other planets besides those specified belong to this system is at present unknown. We have no reason to believe that the boundaries of the planetary system are circumscribed within the range of our discoveries or the limits of our vision. Within the space of little more than half a century, the limits of this system have been expanded to our view to double the extent which they were formerly supposed to comprehend. Instead of an area of only 25,400,000,000 of square miles, it is now found to comprise an extent of 101,700,000,000 of square miles, which is four times the dimensions formerly assigned to it. There would be no improbability in conceiving it extended to at least

triple these dimensions. Within the space of twenty-six years, from 1781 to 1807, no fewer than five primary planets and eight secondaries were discovered, besides a far greater number of comets than had ever before been detected within a similar lapse of years; and therefore it would be obviously rash and premature to conclude that we have now discovered all the moving bodies of our system. Far beyond the limits of even Uranus other planets yet unknown may be performing their more ample circuits around the sun; for we know, from the case of comets, that even throughout those distant regions his attractive power and influence extend. In the immense interval of 900,000,000 of miles between the orbits of Saturn and Uranus, one, if not two planets may possibly exist, though they have hitherto eluded the observation of astronomers. In order to detect such bodies, if any exist, it would be requisite to survey, more minutely than has yet been done, a zone of the heavens extending at least twenty degrees on each side of the ecliptic, marking exactly the minutest objects in every part of it which the most powerful telescopes can enable us to descry. After which a second survey should be made to ascertain if any of the bodies formerly observed be found amissing or have shifted their position. It might likewise be expedient to compare with new observations the stars marked in all the celestial atlases that have hitherto been published, and to note particularly those which are wanting where they were formerly marked, and those that have appeared in certain places where they were formerly unobserved. If a taste for celestial investigations were more common among mankind, and were the number of observers indefinitely increased, there would be no great difficulty in accomplishing such an object; for certain small portions of the heavens might be allotted to different classes of observers, who might proceed simultaneously in their researches, and in a comparatively short period the whole survey might be completed.

It is not improbable that a planet may exist within the space of 37 millions of miles which intervenes between the orbit of Mercury and the sun. But such a body could never be detected in the evening after sunset, as its greatest elongation from the sun could not be supposed to be more than ten or twelve degrees, and, consequently, it would descend below the horizon in about half an hour after sunset, and be-

fore twilight had disappeared. The only chance of detecting such a planet would be when it happened to transit the sun's disk; but as this would happen only at distant intervals, and as it might make the transit in cloudy weather, or when the sun is absent from our hemisphere, there is little prospect of our discovering such a body in this way. It might be of some importance, however, that those who make frequent observations on the sun should direct their attention to this circumstance; as there have been some instances in which dark bodies have been observed to move across the sun's disk in the space of five or six hours, when no other spots were visible. An opaque body of this description was seen by Mr. Lloft and others on the 6th of January, 1818, which moved with greater rapidity across the solar disk than Venus in her transit in 1769. It is possible that a planet within the orbit of Mercury might be detected in the daytime, were powerful telescopes applied to a space of the heavens about ten or twelve degrees around the sun. Small stars have been seen even at noonday with powerful instruments, and, consequently, a planet even smaller than Mercury might be perceived in the daytime. In this case, a round opaque body would require to be placed at a considerable distance from the observer, so as completely to intercept the body of the sun, and about a degree of the heavens all around him; and every portion of the surrounding space, extending to at least twelve degrees in every direction, should then be carefully and frequently examined. Such observations, if persevered in, would undoubtedly afford a chance of detecting any revolving body that might exist within such a limit. But I may afterward have an opportunity of describing more particularly the observations, and the mode of conducting them, to which I allude.

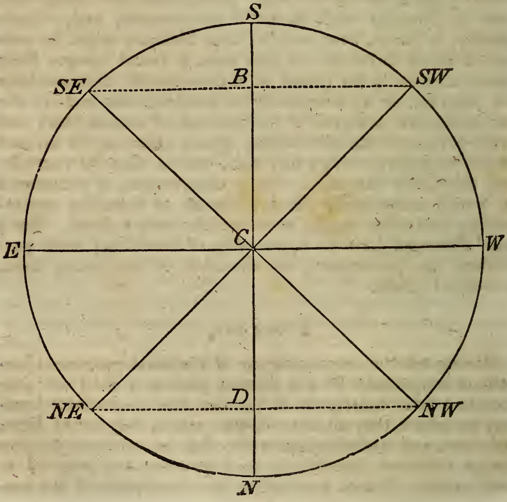
X. THE SUN.

Having taken a cursory survey of the most prominent particulars connected with the primary planets, I shall now proceed to a brief description of the *sun*, that magnificent luminary on which they all depend, from which they derive light, and heat, and vivifying influence, and by whose attractive energy they are directed in their motions and retained in their orbits. Before proceeding to a description of the par-

ticular phenomena connected with the sun, it may be expedient briefly to describe some of his *apparent* motions.

Apparent Motions of the Sun.—The most obvious apparent motion of the sun, which is known to every one, is, that he appears to rise in the morning in an easterly direction, to traverse a certain portion of the sky, and then to disappear in the evening in a direction towards the west. Were we to commence our observations on the 21st of December, in the latitude of 52° north, which nearly corresponds to that of London, we should see the sun rising near the southeast point of the horizon, as at *S E*, Fig. LXVII., describing a comparatively small curve above the horizon, from *S E* to *S W*, in the southern quarter of the heavens, and setting at *S W*, near the southwest. At this season the sun remains only between seven and eight hours above the horizon; and when

Fig. LXVII.



he arrives at *S*, at midday, which is the highest point of his elevation, he is only about fourteen degrees above the horizon, which may be represented by the line *S B*. After disappearing in our horizon in the evening, he describes the large curve from *S W* to *W*, *N*, and *E*, till he again arrives in the morning near the point *S E*. All this curve is described *below* our horizon, and, therefore, the nights at this season are much longer than the days. After this period the sun rises every day at points a little farther to the north, between *S E* and *E*, and sets in corresponding points in the west, between *S W* and *W*, till the 21st of March, when he rises at the point *E*, due east, and sets due west at the point *W*. At this time he moves through the semicircle *E*, *S*, *W*, and at noon he rises to the elevation of thirty-eight degrees above the southern horizon, which may be represented by the line *S C*. This is the period of the vernal equinox, when there is equal day and night throughout every part of the earth, the sun being twelve hours above and twelve hours below the horizon. After this period the sun rises to the north of the easterly point, and sets to the north of the westerly, and the length of the day rapidly advances till the 21st of June, when he rises near the northeast point, *N E*, and sets near the northwest point, *N W*, describing the large curve from *N E* to *E*, *S*, *W*, and *N W*. This period of the year is called the summer *solstice*, when the days are longest, at which time the sun rises at noon to an elevation of 61½ degrees above the horizon, which may be represented by the line *S D*, and he continues above the horizon for nearly seventeen hours. The length of the nights at this time is exactly the same as the length of the days on the 21st of December. The sun's nocturnal arch, or the curve he describes below the horizon, is that which is represented in the lower part of the figure from *N W* to *N E*. In more southern latitudes than fifty-two degrees, the sun rises to a higher elevation at noon; and in higher latitudes his meridian altitude is less than what is stated above. From the time of the summer solstice the days gradually shorten; the sun rises in a more southerly direction till the 23d of September, which is called the *autumnal equinox*, when he again rises in the eastern point of the compass, and every succeeding day at a point still farther to the south, till, on the 21st of December, or the *winter solstice*, he is again seen to rise near the southeast, and afterward to pass through all the apparent variations of motion above described.

Were we residing in southern latitudes, such as those of Buenos Ayres, the Cape of Good Hope, or Van Diemen's Land, the apparent motions of the sun would appear somewhat different. Instead of beholding the sun moving along the *southern* part of the sky from the left hand to the right, we should see him direct his course along the northern part of the heavens from the right hand to the left. In other respects his apparent motions would nearly correspond to those above described. Were we placed in countries under the equator at the time of the equinoxes, the sun at midday would shine directly from the zenith, at which time objects would have no shadows. At all other times the sun is either in the northern or the southern quarter of the heavens. During the one half of the year he shines from the north, and the shadows of objects fall to the south; during the other half he shines from the south, and the shadows of all objects are projected towards the north. This is a circumstance which can never occur in our climate or in any part of the temperate zones. At the equator, too, the days and nights are of the same length, twelve hours each, throughout the whole year. Were we placed at the *poles*, the motion of the sun would present a different aspect from any of those we have described. At the north pole, on the 21st of March, we should see a portion of the sun's disk appear in the horizon after a long night of six months. This portion of the sun would appear to move quite round the horizon every twenty-four hours; it would gradually rise higher and higher till the whole body of the sun made its appearance. As the season advanced, the sun would appear to rise higher and higher, till he attained the altitude of 23 1-2 degrees above the horizon, which would take place on the 21st of June; after which his altitude would gradually decline till the 23d of September, when he would again appear in the horizon. During the whole of this period of six months there is perpetual day, the stars are never seen, and the sun appears to go quite round the heavens every twenty-four hours without setting, in circles nearly parallel to the horizon. After the 23d of September the sun disappears, and a night of six months succeeds, which is occasionally enlivened by the moon, the stars, and the corruscations of the *aurora borealis*, during which period the south pole enjoys all the splendour of an uninterrupted day. In all places within the polar circles, the length of the longest day

varies from twenty-four hours to six months. In the northern parts of Lapland, for example, the longest day is about six weeks; during this time the sun appears to move round the heavens without setting; but at noon, when he comes to the meridian, he is about 40 degrees above the *southern* horizon, and twelve hours afterward he appears elevated about six degrees above the *northern* horizon, from which point he again ascends till he arrives at the southern meridian.

Such are the apparent *diurnal* motions and general aspects of the sun in different parts of the earth, which are owing partly to the inclination of the axis of the earth to the plane of the ecliptic, and partly to the different positions in which a spectator is placed in different zones of the globe. It is almost needless to remark, that these motions of the sun are not *real*, but only *apparent*. While presenting all these varieties of motion, he is still a quiescent body in the centre of the planetary system. By the rotation of the earth round its axis, from west to east, every twenty-four hours, all these apparent motions of the sun are produced. This we have already endeavoured to prove in chap. i., p. 33–37.

Besides the apparent diurnal motion now described, there is another apparent motion of the sun in a contrary direction, which is not so much observed, and that is, his apparent motion from *west* to *east* through the whole circle of the heavens, which he accomplishes in the course of a year. This motion manifests itself by the appearance of the heavens during the night. The stars which lie near the path of the sun, and which set a little time after him, are soon lost in his light, and after a short time reappear in the east a little before his rising. This proves that the sun advances towards them in a direction contrary to his diurnal motion; and hence we behold a different set of stars in our nocturnal sky in summer and in winter. This apparent revolution of the sun is produced by the *annual* motion of the earth round the sun, of which I have already given an explanation (chap. i., p. 37–39), along with certain demonstrative proofs that the sun is the centre of the planetary system (see also chap. ii., p. 52–63).

Distance and Magnitude of the Sun.—To find the exact distance of the sun from the earth is an object which has much interested and engaged astronomers for a century past. The angle of parallax being so small as about eight and a half seconds, rendered it for some time difficult to arrive at an ac-

curate determination on this point, till the transits of Venus in 1761 and 1769. From the calculations founded upon the observations made on these transits, it has been deduced that the distance of the sun is about 95,000,000 of miles. This distance is considered by La Place and other astronomers to be within the 1-87 part of the true distance, so that it cannot be much below 94 millions on the one hand, nor much above 96 millions on the other. Small as this interval may appear when compared with the vast distances of some of the other celestial bodies, it is, in reality, a most amazing distance when compared with the spaces which intervene between terrestrial objects; a distance which the mind cannot appreciate without a laborious effort. It is thirty-one thousand six hundred times the space that intervenes between Britain and America; and were a carriage to move along this space at the rate of 480 miles every day, it would require 542 years before the journey could be accomplished.

The *magnitude* of this vast luminary is an object which overpowers the imagination. Its diameter is 880,000 miles; its circumference, 2,764,600 miles; its surface contains 2,432,800,000,000 of square miles, which is twelve thousand three hundred and fifty times the area of the terraqueous globe, and nearly fifty thousand times the extent of all the habitable parts of the earth. Its solid contents comprehend 356,818,739,200,000,000,* or more than three hundred and fifty-six thousand billions of cubical miles. Were its centre placed over the earth, it would fill the whole orbit of the moon, and reach 200,000 miles beyond it on every hand. Were a person to travel along the surface of the sun, so as to pass along every square mile on its surface, at the rate of thirty miles every day, it would require more than two hundred and twenty millions of years before the survey of this vast globe could be completed. It would contain within its circumference more than thirteen hundred thousand globes as large as the earth, and a thousand globes of the size of Jupiter, which is the largest planet of the system. It is more than five hundred times larger than all the planets, satellites, and comets belonging to our system, vast and extensive as some of them are. Although its density is little more than that of

* In some editions of the "Christian Philospher," under the article *Astronomy*, this number is inaccurately stated; and the number which follows, *two thousand millions*, should be *two hundred millions*

water, it would weigh 3360 planets such as Saturn, 1067 planets such as Jupiter, 329,000 globes such as the earth, and more than *two millions* of globes such as Mercury, although its density is nearly equal to that of lead. Were we to conceive of its surface being peopled with inhabitants at the rate formerly stated, it would contain 681,184,000,000,000, or more than six hundred and eighty billions, which would be equal to the inhabitants of *eight hundred and fifty thousand worlds* such as ours.

Of a globe so vast in its dimensions, the human mind, with all its efforts, can form no adequate conception. If it is impossible for the mind to take in the whole range of the terraqueous globe, and to form a comprehensive idea of its amplitude and its innumerable objects, how can we ever form a conception, approaching to the reality, of a body one million three hundred thousand times greater? We may express its dimensions in figures or in words, but in the present state of our limited powers we can form no mental image or representation of an object so stupendous and sublime. Chained down to our terrestrial mansion, we are deprived of a sufficient range of prospect, so as to form a substratum to our thoughts, when we attempt to form conceptions of such amazing magnitudes. The imagination is overpowered and bewildered in its boldest efforts, and drops its wing before it has realized the ten thousandth part of the idea which it attempted to grasp. It is not improbable that the largest ideas we have yet acquired or can represent to our minds of the immensity of the universe are inferior to a *full and comprehensive idea* of the vast globe of the sun in all its connexions and dimensions ; and, therefore, not only must the powers of the human mind be invigorated and expanded, but also the limits of our intellectual and corporeal vision must be indefinitely extended, before we can grasp the objects of overpowering grandeur which exist within the range of creation, and take an enlightened and comprehensive view of the great Creator's empire. And as such endowments cannot be attained in the present state, this very circumstance forms a presumptive argument that man is destined to an immortal existence, where his faculties will be enlarged and the boundaries of his vision extended, so as to enable him to take a large and comprehensive view of the wonders of the universe, and the range of the Divine government. In the mean time, however, it may be

useful to allow our thoughts to expatiate on such objects, and to endeavour to form as comprehensive an idea as possible of such a stupendous luminary as the sun, in order to assist us in forming conceptions of objects still more grand and magnificent; for the sun which enlightens our day is but one out of countless millions of similar globes dispersed throughout creation, some of which may far excel it in magnitude and glory.

Rotation of the Sun.—This luminary, although it is placed in the centre of the system, in the enjoyment of perpetual day, and stands in no need of light from any other orb, yet is found to have a rotation round its axis. This circumstance seems to indicate that motion is essential to all the bodies of the universe, whether revolving in orbits around another body, or acting as the centres of light and attractive influence. And from what we know of the more distant bodies in the heavens, we have reason to believe that there is none of them in a state of absolute quiescence, but that they are all in incessant motion, either round their axes or around a distant centre. The rotation of the sun was discovered by the motion of certain dark spots across its disk. These spots appear to enter the disk on the east side, to move from thence with a velocity continually increasing till they arrive at the middle of the disk; they then move slower and slower till they go off at the sun's western limb; after which they disappear for about the same space of time they occupied in crossing the disk, and then enter again on the eastern limb, and move onward in the same track as before, unless they suffer a change, as frequently happens, after they disappear from the western limb. The apparent *inequality* in the motion of the spots is purely optical, and is owing to the oblique view we have of the parts of a globe which are near the margin; but the motion is such as demonstrates that the spots are carried round with a uniform and equable motion. From the motion of these spots we learn, 1. That the sun is a globe, and not a flat surface; 2. That it has a rotation round its own axis; and, 3. That this rotation is performed in the same direction as the rotation of the planets and their annual revolutions, namely, according to the order of the signs of the zodiac. The time which spot takes in moving from the eastern to the western limb is thirteen days and nearly sixteen hours, and, consequently, the whole apparent revolution is twenty-seven days and nearly eight hours. But this is not the true period of the sun's ro-

tation; for as the earth has, during this time, advanced in its orbit from east to west, and in some measure followed the motion of the spot, the real time in which the spots perform their revolutions is found, by calculation,* to be twenty-five days, ten hours. Every part of the sun's equator, therefore, moves at the rate of 4532 miles every hour. The axis of the sun, round which this revolution is performed, is inclined 7 degrees 20 minutes to the ecliptic.

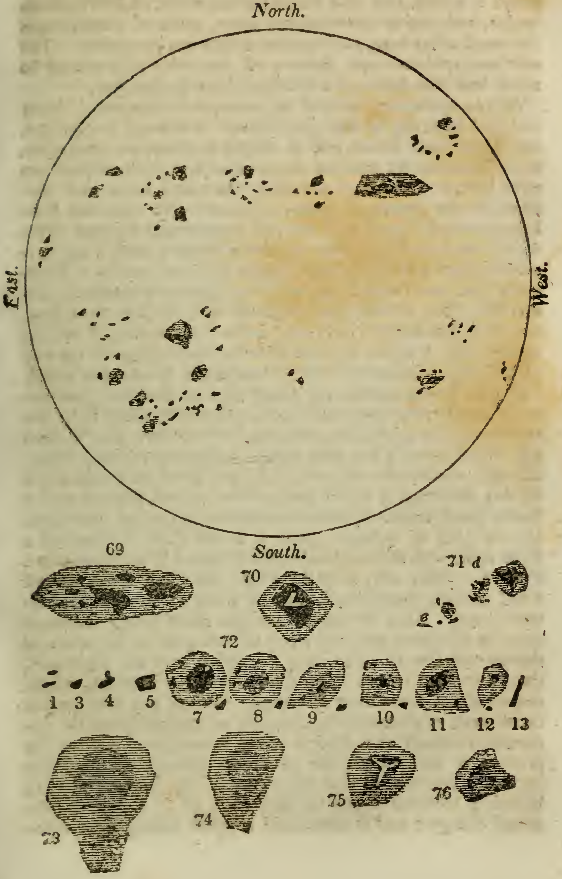
The Solar Spots, and the Physical Construction of the Sun.—Although the sun is the fountain of light, and is incessantly pouring a flood of radiance over surrounding worlds, yet the nature of this vast luminary, and the operations which are going on upon its surface and adjacent regions, are in a great measure involved in darkness. Before stating any opinions on this subject, it may be proper, in the first place, to give a brief description of the phenomena which have been observed on the surface of the sun. The first and most striking phenomenon is the dark spots to which we have alluded. These spots are of all sizes, from one twenty-fifth part of the sun's diameter to the one five hundredth part and under. The larger spots are uniformly dark in the centre, and surrounded with a kind of border or fainter shade, called a *penumbra*. This penumbra, which sometimes occupies a considerable space around the dark nucleus, is frequently of a shape nearly corresponding to that of the black spot. Sometimes two or more dark spots, and a number of small ones are included within the same *penumbra*, and at other times a number of small spots in a train, forming a kind of tail, accompany the larger ones. The *number* of the spots is very various; sometimes there are only two or three, sometimes above a hundred, and sometimes none at all. *Scheiner*, who was among the first that observed these spots, remarks, that "from the year 1611 to 1629 he never found the sun quite clear of spots, except a few days in December, 1624; at other times he was able to count twenty, thirty, and even fifty spots upon the sun at a time." Afterward, during an interval of twenty years, from 1650 to 1670, it is said that scarcely any were to be seen. But, since the beginning of last century, no year has passed, so far as we know, in which spots have not been

* The following is the proportion by which the true rotation is found · 365*d.* 5*h.* 48*m.*+27*d* 7*h.* 37*m.*; or, 392*d.* 13*h.* 25*m.* : 365*d.* 5*h.* 48*m.* : : 27*d* 7*h.* 37*m.* · 25*d.* 9*h.* 56*m.* =the true time of the sun's rotation.

seen. I have had an opportunity of viewing the sun with good telescopes several hundreds of times, but have seldom seen his surface altogether free of spots. In some years, however, they have been far more numerous than in others In the beginning of 1835 comparatively few were seen, but during the latter part of it, the whole of 1836, and up to the present time (September, 1837), they have been exceedingly numerous. On the 16th of November, 1835, with an achromatic telescope, magnifying about a hundred times, I perceived about ten different clusters; and, within the limits of two of the clusters, sixty different spots were counted, and in the whole of the other clusters above sixty more; making in all about 120 spots, great and small. On the 19th of October, 1836, and the 21st of February, 1837, I counted about 130; and on a late occasion I perceived spots of all descriptions to the amount of about 150. Such a number of spots are generally arranged into ten or twelve different clusters, each cluster having one or two large spots, surrounded with a number of smaller ones. Fig. LXVIII. represents the spots of the sun nearly as they appeared on the 19th of October, 1836, some of the smaller spots being omitted. The larger spots are represented on a somewhat larger scale than they should be in proportion to the diameter of the circle; but they present nearly the same relative aspect they exhibited when viewed through the telescope at the time specified. Fig. 69 shows the large spot on a larger scale; and Fig. 70 a large spot which appeared in a subsequent observation, which had a bright streak or two in the centre.

The magnitude of some of the solar spots is astonishing. One of the spots seen November 16, 1835, was found to measure about the *fortieth part* of the sun's diameter; and as that diameter is equal to 880,000 miles, the diameter of the spot must have been 22,000 miles, which is nearly three times the diameter of the earth; and if we suppose it only a flat surface, and nearly circular, it contained 380,133.600 square miles, which is nearly double the area of our globe. The largest of the spots in the figure, including the penumbra, measured about the one twenty-first part of the sun's diameter, and its breadth about the one fifty-fourth part of the same diameter; consequently the length of the spots and penumbra was 41,900 miles, its breadth 16,300, and its area 6,829,700,000 square miles, which would afford room for ten

Fig. LXVIII.


North.
East.
West.
South.
69
70
71 d
72
1
3
4
5
7
8
9
10
11
12
13
73
74
75
76

globes as large as the earth to be placed upon it. It consisted of a dark spot of a longish form, about 12,000 miles in length, and two or three smaller spots, some of them several thousand miles long, all included within one penumbra. The smallest spots we can discern on the solar disk cannot be much less than five or six hundred miles in diameter.

These spots *are subject to numerous changes.* When watched from day to day, they appear to enlarge or contract, to change their forms, and at length to disappear altogether, or to break out on parts of the solar surface where there were none before. Hevelius observed one which arose and vanished in the space of seventeen hours. No spot has been known to last longer than one that appeared in the year 1676, which continued upon the sun above seventy days; but it is seldom that any spots last longer than six weeks. These spots that are formed gradually are generally gradually dissolved; those which arise suddenly are, for the most part, suddenly dissolved. Dr. Long, in his "Astronomy," vol. ii., states, that "while he was viewing the image of the sun cast through a telescope upon white paper, he saw one roundish spot, by estimation not much less in diameter than our earth, break into two, which immediately receded from one another with a prodigious velocity." The Rev. Dr. Wollaston, when viewing the sun with a reflecting telescope, perceived a similar phenomenon. A spot burst in pieces while he was observing it like a piece of ice, which, thrown upon a frozen pond, breaks in pieces and slides in various directions. On the 11th of October, 1833, at $2^h\ 30'$ P.M., I observed a large spot, with several smaller ones behind it, as represented Fig. 71. Next day, at $0^h\ 30'$ P.M., the small spots marked *c* had entirely disappeared, and no trace of them was afterward seen. Each of these spots was more than a thousand miles in diameter, yet they were all changed in the space of twenty-two hours. The spot marked *d*, near the large spot, though at least two or three thousand miles in length, disappeared about three days afterward. When any spot begins to increase or diminish, the nucleus, or dark part, and the penumbra contract and expand at the same time. During the process of diminution, the penumbra encroaches gradually upon the nucleus, so that the figure of the nucleus and the boundary between it and the penumbra are in a state of perpetual change; and it sometimes happens during these varia-

tions, that the encroachment of the penumbra divides the nucleus into two or more parts. These circumstances show that there is a certain connexion between the penumbra and the nucleus; yet it is observed, that when the spots disappear the penumbra continues for a short time visible after the nucleus has vanished. It is likewise observed that the exterior boundary of the penumbra never consists of sharp angles, but is always curvilinear, how irregular soever the outline of the nucleus may be. The portions of the sun on which spots of any description are perceived lie from thirty to fifty degrees on each side of its equator. No spots are ever seen about its polar regions, though I have sometimes seen small spots as distant from the equator as sixty degrees.

Fig. 72 shows the progress of a spot across the sun's disk, from its eastern to its western limb, as observed and delineated by Hevelius, in May, 1644. The figures refer to the number of days on which the spot was observed. On the first day of the observation, when the spot first appeared on the eastern limb, it was seen as represented at 1; the second day it was not visible, by reason of cloudy weather. The third, fourth, and fifth days it gradually increased in bulk; the sixth day it was not seen. On the tenth and following days the spot was vastly increased in bulk, with an irregular atmosphere about it and a dark central spot. Figs. 73, 74, 75, 76, are representations of spots by Sir. W. Herschel. Fig. 75 shows the division of a decaying nucleus or opening, where the luminous passage across the opening resembles a bridge thrown over a hollow.

Besides the dark spots now described, there are other spots which have a bright and mottled appearance, which were formerly termed *faculæ*, and which Sir W. Herschel distinguished by the terms *Nodules*, *Corrugations*, and *Ridges*. These spots are chiefly to be seen near the margin of the sun, in the same latitudes in which the other spots appear. They appear first on the eastern margin, and continue visible for three or four days, but are invisible when they arrive near the middle of the disk, and when they approach near the western limb they are again distinctly visible. This circumstance shows that they are ridges or elevations, which appear in profile when near the limb, but in front or foreshortened when near the middle of the disk, so as to become invisible. They are generally seen in the immediate neighbourhood of

dark spots, and in the places where spots have appeared; and hence, for several years past, when any of these faculæ or ridges have appeared on the eastern margin, I have uniformly been enabled to predict the appearance of a large spot or two within the course of twenty-four or thirty hours; and in more than twenty or thirty instances I have never been disappointed. These faculæ and ridges present a mottled and waving appearance, like that of a country with gentle elevations and depressions, and bear a strong resemblance to certain portions of that surface of the moon, particularly the more level portions of the orb, which present a number of gentle wavings or elevations and depressions. And as those wavings or ridges which appear on the sun are, in a clear atmosphere, as distinctly perceptible as the rough surface of the moon, they must be objects of immense extent and of very great elevation, whether they consist of luminous clouds or of more dense materials. Some of those spaces or ridges have been found to occupy a portion of the solar disk equal to seventy-five thousand miles. They extend over a large portion of the sun's surface, and their shape and position are frequently changing.

Opinions and Deductions respecting the Nature and Constitution of the Sun.—Having described the principal phenomena connected with this immense luminary, we may now consider what conclusions those appearances lead us to deduce respecting its construction and the processes which are going on near its surface. Very vague and foolish opinions have been entertained respecting the nature of the sun ever since the invention of the telescope. It has very generally been considered as a vast body of liquid fire; and in a large volume now before me, published only about a century ago, it is considered as the local place of *hell*. A large map of the sun, copied from the delineations of *Kircher* and *Scheiner*, is exhibited, in which the solar surface is represented as all over covered with flames, smoke, volcanoes, and "great fountains, or ebullitions of fire and light, spread thick over the whole body of it, and in many places *dark spots*, representing dens or caverns, which may be supposed the seats of the blackness of darkness."* In this picture the smoke and flames are

* "An Inquiry into the Nature and Place of Hell." By the Rev. T Swinden, M.A., Rector of Cuxton, in Kent. Second edition, p. 470 London, 1727.

represented as rising beyond the margin of the sun about a ninth part of its diameter, or nearly 90,000 miles; a picture as unlike the real surface of the sun as the gloom of midnight is unlike the splendours of day. But, leaving such extravagant and untenable notions, even some philosophers have held opinions altogether incompatible with reason and with the phenomena presented by the sun: Galileo, Hevelius, and Maupertius considered the spots as *scoria* floating in the inflammable liquid matter of which they conceived the sun to be composed. Others have imagined that the fluid which sends forth light and heat contains a nucleus or solid globe, in which are several volcanoes, like Etna or Vesuvius which from time to time cast forth quantities of bituminous matter up to the surface of the sun, and form those spots which are seen upon it; and that, as this matter is gradually changed and consumed by the luminous fluid, the spots disappear for a time, but are seen to rise again in the same places when those volcanoes cast up new matter. Others, again, have supposed that the sun is a fiery luminous fluid, in which several opaque bodies of irregular shapes are immersed, and that these bodies are sometimes buoyed up or raised to the surface, where they appear like spots; while others imagine that this luminary consists of a fluid in continual agitation, by the rapid motion of which some parts more gross than the rest are carried up to the surface in like manner as scum rises on the top of melted metal or anything that is boiling.

The futility of all such opinions is obvious when we consider attentively all the varieties of the solar phenomena, and when we reflect on the immense magnitude both of the sun itself and of the spots which traverse its surface. What resemblance can there be between such volcanoes as Etna and Vesuvius, and spots on the sun 20,000 miles in diameter, and several times larger than the whole earth? between the vast and sublime operations going forward in this magnificent globe, and "the *scum* and *scoria* of melted metal?" We err most egregiously when we attempt to compare the substances and the puny operations which we see around us on the globe we inhabit, with what takes place on so stupendous a globe as the sun, whose constitution must be so immensely different from that of the planetary bodies, and from everything within the range of our observation on this earth. We talk of volcanoes, of scoria, of boiling metals, of bitumin-

ous matter, of dens, and caverns, and fiery flames in the sun, as if they were as common there as with us; whereas there is every reason to believe that nothing similar to any of these is to be found in the constitution of this vast luminary. We might, with as good reason, attempt to compare the process of vegetation on our globe, and the tides and currents of our ocean, with what takes places on the surface of Jupiter or on the rings of Saturn. In all such cases, it is most becoming rather to acknowledge our ignorance than to caricature and degrade the sublimest works of Omnipotence by our puerile explanations and whimsical theories. The following are some of the more rational conclusions which have been deduced in reference to the constitution of the sun.

In the first place, from a variety of observations, it is now pretty well determined that the solar spots are *depressions*, and not elevations, and that the black nucleus of every spot is the opaque body of the sun seen through an opening in the luminous atmosphere with which it is environed. This was first ascertained by numerous observations made by the late Dr. Wilson, professor of astronomy in the university of Glasgow. This conclusion is founded on the following facts: When any spot is about to disappear behind the sun's western limb, the eastern portion of the umbra first contracts in its breadth, and then vanishes. The nucleus then contracts and vanishes, while the western portion of the umbra still remains visible. When a spot comes into view on the sun's eastern limb, the eastern portion of the umbra first becomes visible, then the dark nucleus, and then the western part of the umbra makes its appearance. When two spots are near each other, the umbra of the one spot is deficient on the side next the other; and when one of the spots is much larger than the other, the union of the largest will be completely wanting on the side next the small one. From various micrometical estimates and calculations in relation to the breadth of the umbrae, and the manner of their appearance and disappearance, the doctor was led to the conclusion that the *depth* of the nucleus or dark part of the spots was, in several instances, from 2000 to nearly 4000 miles. In order to confirm his theory, he constructed a globe representing the sun, with certain hollows cut out to represent the spots or excavations, which were painted black with Indian ink, and the slope or shelving sides of the excavations were distinguished

from the brightness of the external surface by a shade of the pencil, which increased towards the external border. When this artificial sun was fixed in a proper frame, and examined at a great distance with a telescope, the umbra and the nucleus exhibited the same phenomena which are observed on the real sun.*

Sir William Herschel, with his powerful telescopes, made numerous observations on the solar spots, and arrived at the same conclusion as Dr. Wilson had done, that the dark nucleus of the spots is the opaque body of the sun appearing through the openings in its atmosphere, and that the luminous surface of the sun is neither a liquid substance nor an elastic fluid, but luminous or phosphoric clouds floating in the solar atmosphere. He conceives, from the uniformity of colour in the penumbrae or *shallows*, that below these self-luminous clouds there is another stratum of clouds of inferior brightness, which is intended as a curtain to protect the solid and opaque body of the sun from the intense brilliancy and heat of the luminous clouds; and that "the luminous strata are sustained far above the level of the solid body by a transparent elastic medium, carrying on its upper surface, or at some considerably lower level within its depth, a cloudy stratum, which, being strongly illuminated from above, reflects a considerable portion of the light to our eyes, and forms a penumbra, while the solid body, shaded by the clouds, reflects little or none."

What, then, are the conclusions which may be deduced in regard to the constitution of the sun? In the first place, we must admit that, at present, we know very little of the nature of this immense luminary, and of the processes that are going forward on its surface or in its atmosphere. For there is no similar body with which we are intimately acquainted with which we can compare it, and which might enable us to form some definite conceptions of the causes which produce the phenomena it presents. But, secondly, it appears highly probable, if not absolutely certain, that the great body of the sun consists of an opaque solid globe, most probably diversified with elevations and depressions, but of the nature or qualities of this interior globe, and the materials of which it is composed, we are altogether unacquainted. Thirdly, that this opaque globe

* See an elaborate paper on this subject by Dr. Wilson, in vol. lxiv. of the "Philosophical Transactions;" and another, in reply to some objections of La Lande, in the volume for 1783.

is surrounded with a body of light, which it diffuses throughout the planetary system and far beyond it; but whether this light consists of phosphoric clouds in perpetual motion, or how it is produced and kept continually in action, is only matter of conjecture. But, in whatever it consists, it is pretty evident that it forms a shell or covering around the dark body of the sun of several thousand miles in thickness. Fourthly, there are stupendous motions and operations continually going forward in connexion with the surface or the luminous atmosphere of this immense body.

That extensive and amazing operations and processes are going forward on the surface of the sun, or in its immediate vicinity, appears from the immense size of both the dark and luminous spots, and the sudden and extensive changes to which they are frequently subjected. Spots have been observed on the solar disk so large as the one twentieth of the sun's diameter, and, of course, 44,000 miles in lineal extent, comprising an area of one thousand five hundred and twenty millions of square miles. Now it is known from observation that such spots seldom or never last longer than forty-four days, and, consequently, their borders must approach at the rate of at least a thousand miles every day, but in most cases with a much more rapid motion. What, then, shall we think of the motions and operations by which a large spot has been made to disappear in the course of twenty-two hours, as I have sometimes observed, yea, which have disappeared in the course of a single hour? And what shall we think of the process by which a spot as large as the earth was broken into two during the moment of observation, and made to recede from each other, as was observed both by Dr. Long and Dr. Wollaston? (See page 228.) How powerful the forces, how rapid the motions, and how extensive the changes which must have been produced in such cases! Whether we consider such changes to be produced in the solid globe of the sun, or merely in the luminous atmosphere with which it is environed, the scale on which such movements and operations must be conducted is immense, and altogether overpowering to the imagination. What should we think were we to behold the whole of the clouds which float in the earth's atmosphere dissipated in a moment; the continent of America detached from its basis and transported across the Atlantic; or the vast Pacific Ocean, in the course of a few days, over-

whelming with its billows the whole of Asia, Africa, and Europe? Amazing as such changes and revolutions would appear, there are, in all probability, operations and changes, though of a very different description, taking place on the solar surface or atmosphere upon a scale of much larger extent. It is found by calculation that the smallest space containing a visible area which can be distinctly perceived on the sun with good telescopes is about 460 miles; and a circle of this diameter contains about 166,000 square miles. Now those ridges or corrugations, formerly termed *faculæ*, which are seen near the sun's margin, are more than twenty times larger than such a space; they evidently appear to be elevations and depressions on the solar surface, and are almost as distinctly perceptible as the wavings and inequalities on the surface of the moon. How immensely large and elevated, then, must such objects in reality be, when we perceive their inequalities so distinctly at the distance of ninety-five millions of miles! The elevated parts of such objects cannot be less than several hundreds of miles above the level of the valleys or depressions, and extending in length several thousands of miles. Yet, sometimes in a few days, or, at most, in a few weeks, these extensive objects are either dissipated or dark spots appear in their room.

It is evident, then, that stupendous powers are in action, and vast operations are going on in connexion with this august luminary, far surpassing everything within the range of our contemplation in this terrestrial sphere, and of which the human mind can form no distinct conception. These operations appear to be carried forward in a systematic order, and by the regular influence of certain physical agents. But what these agents are; how they produce their effects; wherein they differ in their nature and properties from the physical agents connected with our globe; whether they be employed in keeping up a constant efflux of light and heat to the worlds which roll around; or whether their activities have any relation to intelligent beings connected with the sun, are questions which, in our present state, it is impossible to resolve. But we can easily conceive that scenes of overpowering grandeur and sublimity would be presented to view could we suppose ourselves placed in the immediate vicinity of this luminary. Were we placed within a hundred miles of the solar luminous atmosphere, where the operations which we

now behold at a remote distance would be distinctly perceived, we should doubtless behold a scene of overwhelming magnificence and splendour, and a series of sublime phenomena far surpassing what "eye hath yet seen," or the mind of man can yet conceive. Were we placed within this luminous atmosphere, on the solid surface of the sun, we should doubtless contemplate a scene altogether novel, and still more brilliant and astonishing. To a spectator in this position an opening in the luminous atmosphere several thousands of miles in circumference, where none appeared before, would be presented to his view, through which the stars of heaven might possibly be perceived; and in a short time this opening would gradually close, and he would find himself again surrounded with ineffable splendour; while, at the same time, he might have a view of the physical agents by which these astonishing effects are produced. In a short time another opening of a different kind would be perceived, and other scenes and transformations would be exhibited to the view in regular succession. That such scenes would actually be exhibited is a natural deduction from the theory (which may be considered as established) that the sun consists of a solid globe, surrounded with a luminous atmosphere, and that the dark spots are the openings in that luminous fluid.

It appears, then, that the sun which we daily behold is a body of ineffable magnitude and splendour, and that the most magnificent operations are incessantly going forward on its surface or in its immediate vicinity. It is, indeed, a kind of *universe* in itself, the magnitude, and extent, and grandeur of which, and the vast and sublime operations connected with its physical constitution, surpass the powers of the human mind to form any adequate conception. We are destitute of a *substratum* of thought for enabling us to form a comprehensive conception on this subject. When we ascend to the top of Mount Etna or Mount Blanc, and survey the vast group of surrounding objects which appear around and beneath us when the morning sun illuminates the landscape, we behold one of the largest and most expansive objects that can meet our eye in this sublunary scene; and we can compare it with objects that are smaller and with those that are somewhat larger. But the amplitude of such a scene extends only to a hundred or a hundred and fifty miles in every direction, which is less than the least visible point or spot which we can per-

ceive on the sun with the most powerful telescopes. Were we transported to a point five or six thousand miles above the surface of the earth, so as to take in nearly at one view the whole hemisphere of our globe; and were our eyes to be strengthened so as to be able to perceive every part of its surface distinctly, our ideas of *magnitude* would be vastly enlarged, and we should be enabled to form more correct and comprehensive conceptions than we can now do of the still greater magnitudes of many of the celestial bodies. But even such an object as the whole of the earth's hemisphere, seen at one comprehensive view, would afford us comparatively little assistance in forming an adequate conception of such a stupendous globe as the sun; it would not equal the idea of magnitude which we ought to attach to one of the smaller spots on its surface. For the area of the solar surface is twenty-four thousand seven hundred times greater; so that 24,700 scenes equal in magnitude to the hemisphere of our globe must pass between us in review before we could acquire a comprehensive and adequate idea of the expansive surface of the sun. And were a scene of this description to pass before our eyes every two hours, till an extent equal to the area of the sun passed under our view, and were twelve hours every day allotted for the observation, it would require more than eleven years before such a rapid survey of this vast luminary could be completed. But, as we can have no adequate idea of a scene comprehending a whole hemisphere of our globe, let us compare the view from Mount Etna with the amplitude of the sun. "There is no point on the surface of the globe," says Mr. Brydone, "that unites so many awful and sublime objects as the top of Etna, and no imagination has dared to form an idea of so glorious and magnificent a scene. The body of the sun is seen rising from the ocean, immense tracts both of sea and land intervening; the islands of Pinari, Alicudi, Lipari, Stromboli, and Volcano, with their smoking summits, appear under your feet, and you look down on the whole of Sicily as on a map, and can trace every river through all its windings from its source to its mouth. The view is absolutely boundless on every side, so that the sight is everywhere lost in the immensity." Yet this glorious and expansive prospect is comprised within a circle about 240 miles in diameter and 754 in circumference, containing 45,240 square miles, which is only 1-53,776,608 part of the

surface of the sun; so that fifty-three millions, seven hundred and seventy-six thousand landscapes, such as beheld from Mount Etna, behooved to pass before us before we could contemplate a surface as expansive as that of the sun; and if every such landscape were to occupy two hours in the contemplation, as supposed above, it would require *twenty-four thousand five hundred and fifty-four years* before the whole surface of this immense globe could be in this manner surveyed; and, after all, we should have but a very imperfect conception of the *solid contents* of the sun, which contains 356,818,739,200,000,000 of cubical miles, which number is 146,670 times greater than the number of square miles upon its surface.

What a glorious idea, then, does such an object as the sun present to us of the GRANDEUR of the Deity and the ENERGIES of OMNIPOTENCE! There is no single object within the range of our knowledge that affords a more striking and august emblem of its Great Creator. In its lustre, in its magnitude, in its energy, in its boundless influence, and its beneficial effects on this earth and on surrounding worlds, there is a more bright display of Divine perfection than in any other material being with which we are acquainted:

> "Great source of day! best image here below
> Of thy Creator! ever pouring wide
> From world to world, the vital ocean round,
> On Nature write, with every beam, his praise."

Could such a magnificent orb have been produced by a fortuitous concourse of atoms, and placed in its proper position to distribute light and attractive influence to the worlds which roll around it? Could chance have directed the distance at which it should be placed from the respective planets, or the size to which it should be expanded, in order to diffuse its energies to the remotest part of the system? Could chance have impressed upon it the laws requisite for sustaining in their courses all the bodies dependant upon it, or have endowed it with a source of illumination which has been preserved in action from age to age? To affirm such positions would be to undermine and annihilate the principles of all our reasonings. The existence of the sun proves the existence of an Eternal and Supreme Divinity, and at the same time demonstrates his omnipotent power, his uncon-

trollable agency, the depths of his wisdom, and the riches o. his beneficence. If such a luminary be so glorious and incomprehensible, what must its Great Creator be? If its splendour be so dazzling to our eyes, and its magnitude so overpowering to our imagination, what must He be who lighted up that magnificent orb, and bade a retinue of worlds revolve around it; who "dwells in light inaccessible, to which no mortal eye can approach?" If the sun is only one out of many myriads of similar globes dispersed throughout the illimitable tracts of creation, how great, how glorious, how far surpassing human comprehension must be the plans and the attributes of the infinite and eternal Creator! "His greatness is unsearchable, and his ways past finding out." Could we thoroughly comprehend the depths of his perfections or the grandeur of his empire, he would cease to be God, or we should cease to be limited and dependant beings. But, in presenting to our view such magnificent objects, it is evidently his intention that we should rise in our contemplations from the effect to the cause, from the creature to the Creator, from the visible splendours and magnificence of creation to the invisible glories of Him who sits on the throne of the universe, "whose kingdom ruleth over all, and before whom all nations are counted as less than nothing and vanity."

It might here form a subject of inquiry, *whether there be any reason to believe that the sun is inhabited?* Most astronomers have been disposed to answer this question in the negative. Sir W. Herschel, however, and several others, consider it as not altogether improbable that the sun is peopled with rational beings. Viewing this luminary as consisting of a dark solid nucleus, surrounded by two strata of clouds the outermost the region of that light and heat which is diffused to the remotest parts of the system, they conceived that the interior stratum was intended to protect the inhabitants of the sun from the fiery blaze of the sphere of light and heat with which they are surrounded. On either side of this question it becomes us to speak with diffidence and modesty We ought not to set limits to the wisdom and arrangements of the Creator by affirming that rational beings could not exist and find enjoyment on such a globe as the sun on account of the intensity of light and heat which for ever prevails in that region For it is probable that the luminous

matter that encompasses the solid globe of the sun does not derive its splendour from any intensity of heat. If this were the case, the parts underneath, which are perpetually in contact with that glowing matter, would be heated to such a degree as to become luminous and bright, whereas we find that they have uniformly a *dark* appearance; so that it is possible the interior region of the sun may be in a state of comparatively low temperature. For anything we know to the contrary or can demonstrate, the sun may be one of the most splendid and delightful regions of the universe, and scenes of magnificence and grandeur may be there displayed far surpassing anything that is to be found in the planets which revolve around it, and its population may as far exceed in number that of other worlds as the immense size of this globe exceeds that of all the other bodies in the system. But, on the other hand, we know too little of the nature and constitution of the sun, and the plans of Divine Wisdom, to warrant us to make any positive assertions on this point. Although no intelligent beings were connected with this great luminary, its boundless influence in the planetary system; its being the soul and centre of surrounding worlds; its diffusing light, and heat, and genial influences of various kinds, to all the tribes of their inhabitants; and its cementing them all by its attractive energy in one harmonious system, are reasons sufficient for the creation of this vast globe, without the influence of which perpetual darkness would ensue, the planets would start from their spheres, and the whole system soon become one universal wreck.

It is owing to the existence of the sun that our globe is a habitable world and productive of enjoyment. Almost all the benign agencies which are going forward in the atmosphere, the waters, and the earth, derive their origin from its powerful and perpetual influence. Its light diffuses itself over every region, and produces all that diversity of colouring which enlivens and adorns the landscape of the world, without which we should be unable to distinguish one object from another. By its vivifying action, vegetables are elaborated from inorganic matter, the sap ascends through their myriads of vessels, the flowers glow with the richest hues, the fruits of autumn are matured, and become, in their turn, the support of animals and of man. By its heat the waters of the rivers and the ocean are attenuated and carried to the higher re-

gions of the atmosphere, where they circulate in the form of vapour till they again descend in showers, to supply the sources of the rivers and to fertilize the soil. By the same agency all winds are produced, which purify the atmosphere by keeping it in perpetual motion, which propel our ships across the ocean, dispel noxious vapours, prevent pestilential effluvia, and rid our habitations of a thousand nuisances. By its attractive energy the tides of the ocean are modified and regulated, the earth conducted in its annual course, and the moon sustained and directed in her motions. Its influence descends even to the mineral kingdom, and is felt in the chymical compositions and decompositions of the elements of nature. The disturbances in the electric equilibrium of the atmosphere, which produce the phenomena of thunder, lightning, and rain, and the varieties of terrestrial magnetism; the slow degradation of the solid constituents of the globe, and their diffusion among the waters of the ocean, may all be traced, either directly or indirectly, to the agency of the sun. It illuminates and cheers all the inhabitants of the earth from the polar regions to the torrid zone. When its rays gild the eastern horizon after the darkness of the night, something like a new creation appears. The landscape is adorned with a thousand shades and colours; millions of insects awake and bask in its rays; the birds start from their slumbers, and fill the groves with their melody; the flocks and herds express their joy in hoarser acclamations; "man goeth forth to his work and to his labour;" all nature smiles, and "the hills rejoice on every side." Without the influence of this august luminary, a universal gloom would ensue, and surrounding worlds, with all their trains of satellites, would be shrouded in perpetual darkness. This earth would become a lifeless mass, a dreary waste, a rude lump of inactive matter, without beauty or order. No longer should we behold the meadows clothed with verdure, the flowers shedding their perfumes, or "the valleys covered with corn." The feathered songsters would no longer chant their melodious notes; all human activity would cease; universal silence would reign undisturbed, and this huge globe of land and water would return to its original chaos.

Hence it appears that there is a sufficient reason for the creation of this powerful luminary, although no sensitive or intelligent beings of any description were placed on its sur-

face. But, at the same time, when we consider the infinite wisdom and intelligence of the Divine mind, and that the thoughts and the ways of God as far surpass the thoughts of man as the heavens in height surpass the earth; when we consider that animated beings on our own globe are found in situations where we should never have expected them; that every puddle and marsh, and almost every drop of water, is crowded with living beings; and that even the very viscera in the larger animals can afford accommodation for sentient existence, it would be presumptuous in man to affirm that the Creator *has not placed* innumerable orders of sentient and intelligent beings, with senses and constitutions accommodated to their situations, throughout the expansive regions of the sun.

It has been a question which has exercised the attention of some astronomers, *whether the solar phenomena have any effect upon the weather* or the productiveness of our seasons. Sir W. Herschel was of opinion, that when the corrugations and openings of the solar atmosphere are numerous, the heat emitted by the sun must be proportionably increased, and that this augmentation must be perceptible by its effects on vegetation; and, by comparing the solar appearances as given by La Lande with the table of the price of wheat in Smith's "Wealth of Nations," he obtained results which he considered as favourable to his hypothesis. But it is evident that we are not yet in possession of such a series of facts in relation to this subject as will warrant us to draw any general conclusions. Besides, we know too little of the construction of the sun, and the nature of those processes which are going on in its atmosphere, to be able to determine the proportion of light and heat which particular phenomena indicate. So far as my own observation goes, I should be disposed to adopt an opposite conclusion, namely, that in those years when the spots of the sun are numerous, the seasons are colder and more unproductive of vegetation. This was remarkably the case in the year 1816, when the solar spots were extremely numerous, and when the harvest was so late and scanty that the price of all kinds of grain was more than double what it had been before or what it has been since. The year 1836, and the present year, 1837, afford similar examples; for, during eighteen months past, the solar spots have been more numerous than in any other period in my recollection; and the cold of the

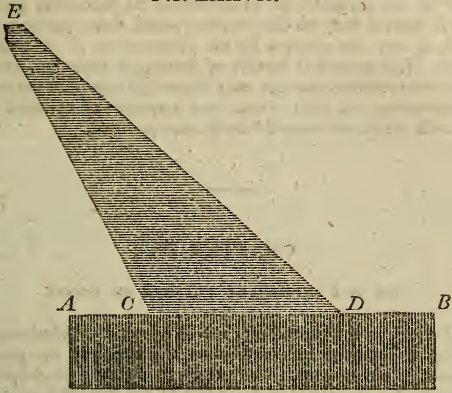
summer and harvest of 1836, and of the winter and spring of 1837, and its unfavourable effects on vegetation, were greater than what had been experienced for more than twenty years before. But on this point we are not yet warranted to draw any positive conclusions. Before we can trace any general connexion between the solar spots and the temperature and vegetation of our globe in any particular season, we must endeavour to ascertain the effects produced on vegetation, not only in two or three particular countries which lie adjacent to each other, but over all the regions of the earth. It may be proper to direct our future observations to this point, as they might probably lead to some important results; but a considerable period behooved to elapse before we could be warranted to deduce any definite conclusions.

Whether the sun has a progressive motion in absolute space is another question which has engaged the attention of astronomers. If the sun have such a motion directed to any quarter of the heavens, the stars in that quarter must apparently recede from each other, while those in the opposite region will seem gradually to approach. Sir W. Herschel found that the apparent proper motion of forty-four stars out of fifty-six are very nearly in the direction which should result from a motion of the sun towards the constellation *Hercules*, or to a point of the heavens whose right ascension is 250° 52½′, and north declination 49° 38′. "No one," says Sir John Herschel, "who reflects with due attention on the subject, will be inclined to deny the high probability, nay, *certainty*, that the sun *has* a proper motion in *some* direction." But it appears to be yet undetermined by modern astronomers to what point in the heavens this motion is directed, and whether it be in a straight line or in a portion of the circumference of an immense circle. If the sun, then, has a proper motion in space, all the planetary bodies and their satellites, along with the comets, must partake of it; so that, besides their own proper motions around this luminary, they are likewise carried along with the sun through the depths of infinite space with a velocity perhaps as great as that with which they are carried round in their orbits. Our earth will therefore partake of three motions: one round its axis, another round the sun, and a third in the direction in which the sun is moving; and, consequently, it is probable that we shall never again occupy that portion of absolute space through

which we are now passing throughout all the succeeding periods of eternity.

The Zodiacal Light.—The zodical light is a phenomenon which has been generally considered as connected with the sun. This light appears to have been noticed by Mr. Childrey about the year 1660; but it was afterward more particularly noticed and described by Cassini in the spring of 1683, which was the first time he had seen it, and he observed it for about eight days. It appears generally in a conical form, having its base directed towards the body of the sun and its point towards some star in the zodiac. Its light is like the milky way, or that of the faint twilight, or the tail of a comet, thin enough to let the stars be seen through it, and seems to surround the sun in the form of a lens, the plane of which is nearly coincident with the plane of the sun's equator. The apparent angular distance of its vertex from the sun varies from 40 to 90 degrees, and the breadth of its base, perpendicular to its axis, from 8 to 30 degrees. It is supposed to extend beyond the orbit of Mercury, and even as far as that of Venus, but never so far as the orbit of the earth. This light is weaker in the morning when day is coming on than at night when darkness is increasing, and it disappears in full moonlight or in strong twilight. In north latitudes it is most conspicuous after the evening twilight about the end of February and the beginning of March; and before the appearing of the morning twilight, about the beginning of October; for at those times it stands most erect above the horizon, and is therefore farthest removed from the thick vapours and the twilight. About the time of the winter solstice it may likewise be seen in the mornings; but it is seldom perceptible in summer on account of the long twilights. It is more easily and more frequently perceived in tropical climates, and particularly near the equator, than in our country, because in those parts the obliquity of the equator and zodiac to the horizon is less, and because the duration of twilight is much shorter. Humboldt observed this light at Caraccas on the 18th of January, after seven o'clock in the evening. The point of the pyramid was at the height of 53 degrees; and the light totally disappeared about half past nine, about 3¾ hours after sunset, without any diminution in the serenity of the sky. On the 15th of February it disappeared 2 hours and 50 minutes after sunset, and the altitude of the pyramid on

Fig. LXXVII.



both these occasions was 50 degrees. The above figure exhibits a view of this phenomenon as it is seen about the beginning of March, at seven o'clock in the evening, when the twilight is ending, and the equinoctial point in the horizon. *A B* represents the horizon; *C D* the base of the luminous triangle; and *E* its apex, pointing towards the Pleiades or the star Aldebaran, its axis forming an angle of between 60 and 70 degrees with the horizon.

Various opinions have been entertained as to the cause of this phenomenon; but as it uniformly accompanies the sun, it has been generally ascribed to an atmosphere of immense extent surrounding that luminary, and extending beyond the orbit of Mercury. According to this opinion, the zodiacal light is considered as a section of this atmosphere; but this opinion now appears extremely dubious. Professor Olmsted, of Yale College, the celebrated Arago, Biot, and others, are now disposed to identify this phenomenon with the cause that produces the "November Meteors," or shooting stars, which have, of late, excited so great a degree of public attention. It appears highly probable that these meteors derive their

origin from a nebulous body which revolves round the sun, and which, in certain parts of its course, comes very near the orbit of the earth, so as to be within its attractive power; and if such a body be the source whence these meteors proceed, it may also account for the phenomenon of the zodiacal light. The subject is worthy of particular attention, and future observations may not only throw light on this particular phenomenon, but open to our view a species of celestial bodies with which we were formerly unacquainted.

CHAPTER IV.

ON THE SECONDARY PLANETS OR MOONS.

Having, in the preceding chapter, given a detailed account of the phenomena connected with the sun and the primary planets of our system, I shall now proceed to a brief description of what is known in reference to the satellites or moons which accompany several of the primary planets.

A secondary planet or satellite is a body which revolves around a primary planet as the centre of its motion, and which is at the same time carried along with its primary round the sun. The satellites form a system, in connexion with their primaries, similar to that which the planets form in connexion with the sun. They revolve at different distances from their primaries; they are regulated according to the laws of Kepler formerly alluded to; their orbits are circles or ellipses of very moderate eccentricity; in their motions around their primaries they describe areas very nearly proportional to the times; and the squares of the periodical times of all the satellites belonging to each planet are in proportion to each other as the cubes of their distances (see page 53). The planets around which satellites have been discovered are, the earth, Jupiter, Saturn, and Uranus. Of the satellites belonging to these bodies I shall present a brief sketch in the order in which they are here mentioned.

I. OF THE EARTH'S SATELLITE, OR THE MOON.

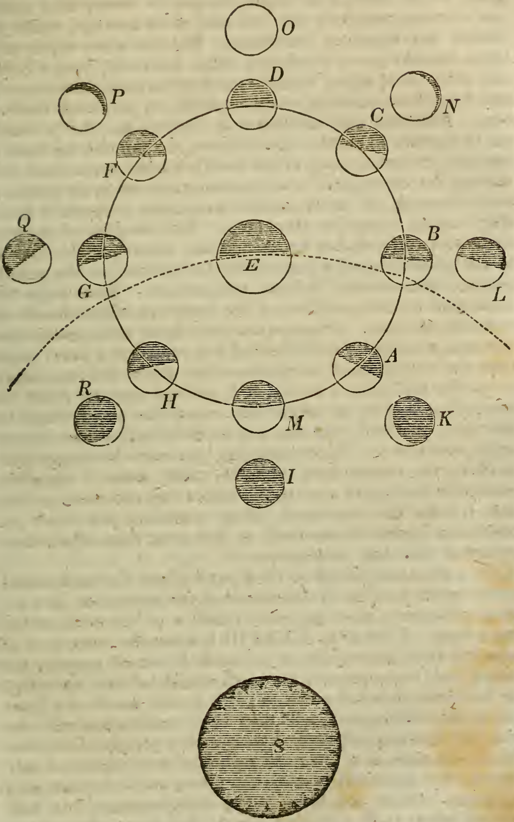
Before proceeding to a particular description of this nocturnal luminary, I shall present a brief sketch of its *apparent motions*.

The moon, like all the other celestial bodies, appears daily to rise in an easterly direction, and to set in the western parts of the horizon. Its apparent motion in this respect is similar to that of the sun, formerly described, and is owing to the diurnal motion of the earth. Its *real motion* round the earth is in a contrary direction, namely, from west to east, or in the same direction in which all the planets move round the sun. This motion may be traced every lunation, but more distinctly during the spring months, when the moon, in the first quarter, appears in a high degree of north declination, and when its crescent is sometimes visible within thirty-six hours of the change. About this period, on the second or third day of the moon's age, it will be seen in the west after sunset at a small elevation above the horizon, and exhibiting the form of a slender crescent. On the next evening it will appear at a still higher elevation at the same hour, having moved about thirteen degrees further to the east, and its crescent will appear somewhat larger. Every succeeding day it will appear at a greater elevation, and farther to the east than before, and its crescent will appear larger, till about the seventh or eighth day, when it will be seen in the south when the sun is setting in the west, at which time it assumes the appearance of a semicircle, or half moon. During this period the horns of the crescent point towards the east, the enlightened part of the lunar disk being turned towards the sun. After the first quarter, or the period of half moon, the lunar orb still keeps on its course to the eastward, and the portion of its enlightened disk is gradually enlarged, till about the fifteenth day of the moon's age, when it appears as a full enlightened hemisphere, and rises in the east about the time when the sun is setting in the west. In this position it is said to be in *opposition* to the sun, and passes the meridian about midnight. After this period the enlightened part of its disk gradually diminishes, and it rises at a later hour, till, in the course of seven days, it is again reduced to a semicircle, and is seen only during one half of the night. Some nights after it appears reduced to a crescent, having its points or horns turned towards the *west*, the sun

being then to the east of it. After this it rises but a little time before the sun, and is seen only early in the morning; and its crescent daily diminishes till it at length disappears, when it rises at the same time with the sun; and after having been invisible for two or three days, it reappears in the evening in the west a little after sunset. During this period the moon has made a complete circuit round the heavens from west to east, which is accomplished in twenty-nine days and a half, in which period it passes through all the phases now described. The progressive motion from west to east, every day, may be traced by observing the stars which lie nearly in the line of the moon's course. If a star be observed considerably to the eastward of the moon on any particular evening, on the following evening it will appear about thirteen degrees nearer the star, and will afterward pass to the eastward of it, and every succeeding day will approach nearer to all the other stars which lie near the line of its course to the eastward. The reason why the moon appears under the different phases now described will appear from the following figure.

In this diagram *S* represents the sun; *E* the earth; and *M*, *A*, *B*, *C*, *D*, *E*, *F*, *G*, *H*, the moon in different positions in its orbit round the earth. When the moon is at *M*, as seen from the earth, her dark side is completely turned to the earth; and she is consequently invisible, as at *I*, being nearly in the same part of the heavens with the sun. She is in this position at the period termed *new moon*, when she is also said to be *in conjunction* with the sun. When she has moved from *M* to *A* a small part of her enlightened hemisphere is turned towards the earth, when she appears in the form of a *crescent*, as at *K*. In moving from *A* to *B* a larger portion of her enlightened hemisphere is gradually turned towards the earth; and when she arrives at *B* the one half of her enlightened hemisphere is turned to the earth, and she assumes the figure of a *half moon*, as at *L*. When arrived at *C* she appears under what is called a *gibbous* phase, as at *N*, more than one half of her enlightened disk being turned to the earth. At *D* her whole enlightened hemisphere is turned to our view, and she appears a *full moon*, as at *O*. After this period she again decreases, turning every day less and less of her enlightened hemisphere to the earth, so that at *F* she appears as at *P*; at *G* a half moon on the decline, as at *Q*; at *H* a crescent, as at *R*; and at *M* she is again in conjunction with the sun,

FIG. LXXVIII.



when her dark side is turned to the earth as before. The moon passes through all these changes in twenty-nine days, twelve hours, and forty-four minutes, at an average, which is termed her *synodical revolution*. But the time which she takes in making one revolution round the earth, from a fixed star to the same again, is only twenty-seven days, seven hours, and forty-three minutes, which is called her *periodical revolution*. For, after one revolution is finished, she has a small arc to describe in order to get between the sun and the earth; because, in consequence of the earth's motion in the same direction, the sun appears to be advancing forward in the ecliptic, and, of course, the moon requires some time to overtake him, after having finished a revolution. This surplus of motion occupies two days, five hours, and one minute, which, added to the periodical, make the synodical revolution, or the period between one new or full moon and another. This might be illustrated by the revolution of the hour and minute-hands of a watch or clock. Suppose the hour-hand to represent the sun, and a complete revolution of it to represent a year; suppose the minute-hand to represent the moon, and its circuit round the dial-plate a month, it is evident that the moon or minute-hand must go more than round the circle where it was last conjoined with the sun or hour-hand before it can again overtake it. If, for example, they were in conjunction at XII., the minute-hand or moon must make a complete revolution and above one twelfth before they can meet, a little past I.; for the hour-hand, being in motion, can never be overtaken by the minute-hand at that point from which they started at their last conjunction.

To a spectator placed on the lunar surface, the earth would every month exhibit all the phases of the moon, but in a reverse order from what the moon exhibits to the earth at the same time. Thus (Fig. LXXVIII.), when the moon is at *D* only the dark hemisphere of the earth is turned towards the moon, and, consequently, the earth would be then invisible; so that when it is full moon to us, it is new moon to a lunar inhabitant; as the earth will then be in conjunction with the sun, and nothing but its dark hemisphere presented to view. When the moon is at *P* a small portion of the enlightened half of the earth is turned towards the moon, and it appears as a crescent. When she is at *Q* the earth appears as a half moon; when at *R* a gibbous phase; and when she is at *I*,

the time of new moon to us, the earth then shines on the dark side of the moon with a full enlightened hemisphere. It is owing to this circumstance, that when the new moon first appears like a slender crescent, her dark hemisphere is seen illuminated with a faint light, perceptible even to the naked eye; and with the help of a telescope we are enabled, by this faint illumination, to distinguish the prominent spots on this portion of the lunar disk. This faint light, therefore, is no thing else than *the moonlight of the moon*, produced by the earth shining with nearly a full face upon the dark surface of the moon. And as the surface of the earth is thirteen times larger than the surface of the moon, the light reflected from the earth will be nearly equal to that of thirteen full moons. As the age of the moon increases, this secondary light is gradually enfeebled, and after the seventh or eighth day from the change it is seldom visible. This arises from the diminution of the enlightened part of the earth, which then appears only like a half moon, approaching to a crescent, and, consequently, throws a more feeble light upon the moon, which is the more difficult to be perceived as the enlightened part of the moon increases.

Rotation of the Moon.—While the moon is performing her revolution round the earth every month, she is also gradually revolving round her axis; and it is somewhat remarkable that her revolution round her own axis is performed *in the same time* as her revolution round the earth. This is inferred from the circumstance that *the moon always turns the same face to the earth*, so that we never see the other hemisphere of this globe. For if the moon *had no rotation upon an axis*, she would present every part of her surface to the earth. This does not, at first sight, appear obvious to those who have never directed their attention to the subject. Any one, however, may convince himself of the fact by standing in the centre of a circle, and causing another person to carry round a terrestrial globe, without turning it on its axis, when he will see every part of the surface of the globe in succession; and in order that one hemisphere only should be presented to his view, he will find that the globe will require to be gradually turned round its axis, so as to make a complete rotation during the time it is carried round the circle. The axis of the moon is inclined 88° 29′ to the ecliptic, so that it is nearly perpendicular to it. Although the moon presents nearly the

same side to the earth in all its revolutions around it, yet there is perceived a certain slight variation in this respect. When we look attentively at the disk of the moon with a telescope, we sometimes observe the spots on her eastern limb, which were formerly visible, concealed behind her disk, while others appear on her western limb which were not seen before. The spots which appear on the western limb withdraw themselves behind the limb, while the spots which were concealed behind the eastern limb again appear. The same phenomena are observed in the north and south limb of the moon, so that the spots sometimes change their positions about three minutes on the moon's disk, or about the eleventh part of her diameter. This is termed *the libration of the moon;* the one her libration in *longitude*, and the other her libration in *latitude.*

From what we have stated above in relation to the phases and motions of the moon, it is evident that the moon is a dark body, like the earth, and derives all its light from the sun, for its enlightened side is always turned towards that luminary. It likewise derives a faint light by the reflection of the sun's rays from the earth, in the same way as we derive a mild light from the moon. And as the earth has an uneven surface, composed of mountains and vales, so the moon is found to be diversified with similar inequalities. It is owing to these inequalities, or the *roughness* of the moon's surface, that the light of the sun is reflected from it *in every direction;* for, if the surface of the moon were perfectly smooth, like a polished globe or speculum, her orb would be invisible to us; except, perhaps, at certain times, when the image of the sun, reflected from it, would appear like a bright lucid point. This may be illustrated by the following experiment. Place a silver globe, perfectly polished, about two inches diameter, in the sun; the rays which fall upon it being reflected variously, according to their several incidences, upon the convex surface, will come to our eye only from one point of the globe, which will therefore appear a small bright spot, but the rest of the surface will appear dark. Let this globe then be boiled in the liquor used for whitening silver, and placed in the sun; it will appear in its full dimensions all over luminous; for the effect of that liquor is to take off the smoothness of the polish, and make the surface rough, and then every point of it will reflect the rays of light in every direction.

The moon is the nearest to the earth of all the celestial bod-

ies, and is a constant attendant upon it at all seasons. Her distance from the centre of the earth is, in round numbers, 240,000 miles, or somewhat less than a quarter of a million; which is little more than the fourth part of the diameter of the sun. Small as this distance is compared with that of the other planets, it would require five hundred days, or sixteen months and a half, for a steam-carriage to move over the interval which separates us from the lunar orb, although it were moving day and night at the rate of twenty miles every hour. In her motion round the earth every month, she pursues her course at the rate of 2300 miles an hour. But she is carried at the same time, along with the earth, round the sun every year, so that her real motion in space is much more rapid than what has now been stated; or while she accompanies the earth in its motion round the sun, which is at the rate of 68,000 miles an hour, she also moves thirteen times round the earth during the same period, which is equal to a course of nearly twenty millions of miles.

The moon's orbit is inclined to the ecliptic in an angle of 5° 9′; so that, in one part of her course, she is above, and in another below the level of the earth's orbit. It is owing to this circumstance that this orb is not eclipsed at every full moon and the sun at every new moon, which would regularly happen did the moon move in an orbit exactly coincident with the plane of the ecliptic. The moon's orbit, of course, crosses the orbit of the earth in two opposite points, called her *nodes;* and it is only when the new or full moon happens at or near these nodes that an eclipse of the sun or moon can take place; for it is only when she is in such a position that the sun, the moon, and the earth are nearly in a straight line, and that the shadow of the one can fall upon the other. The shadow of the moon falling upon any part of the earth produces an eclipse of the sun, and the shadow of the earth falling upon the moon causes an eclipse of the moon. An eclipse of the moon can only take place at *full moon*, when the earth is between the sun and the moon; and an eclipse of the sun can only happen at *new moon*, when the moon comes between the sun and the earth. Lunar eclipses are visible in all parts of the earth which have the moon above their horizon, and are everywhere of the same magnitude and duration; but a solar eclipse is never seen throughout the whole hemisphere of the earth where the sun is visible; as the moon's disk is too

small to hide the whole, or any part of the sun from the whole disk or hemisphere of the earth. Nor does an eclipse of the sun appear the same in all parts of the earth where it is visible, but when in one place it is total, in another it is only partial.

The moon's orbit, like those of the other planets, is in the form of an *ellipse*, the *eccentricity* of which is 12,960 miles, or about 1-37 part of its longest diameter. The moon is, therefore, at different distances from the earth in different parts of her orbit. When at the greatest distance from the earth, she is said to be in her *apogee;* when at the least distance, in her *perigee.* The nearer the moon is to the periods of *full* or *change*, the greater is her velocity; and the nearer to the quadratures, or the periods of half moon, the slower she moves. When the earth is in its *perihelion*, or nearest the sun, the periodical time of the moon is the greatest. The earth is at its perihelion in winter, and, consequently, at that time the moon will describe the largest circle about the earth, and her periodical time will be the longest; but when the earth is in its *aphelion*, or farthest from the sun, which happens in summer, she will describe a smaller circle, and her periodical time will be the least, all which circumstances are found to agree with observation. These and many other irregularities in the motion of this orb, which it would be too tedious to particularize, arise from the attractive influence of the sun upon the lunar orb in different circumstances and in different parts of its course, so as to produce different degrees of accelerated and retarded motion. The irregularities of the moon's motion have frequently puzzled astronomers and mathematicians, and they render the calculations of her true place in the heavens a work of considerable labour. No less than thirty equations require to be applied to the *mean* longitude in order to obtain the *true*, and about twenty-four equations for her latitude and parallax; but to enter minutely into such particulars would afford little satisfaction to general readers.

Description of the surface of the Moon, as seen through telescopes.—Of all the celestial bodies, the telescopic view of the moon presents the most interesting and variegated appearance. We perceive, as it were, a map or model of another world, resembling in some of its prominent features the world in which we dwell, but differing from it in many of its

minute arrangements. It bears a certain analogy to the earth in some of the mountains and vales which diversify its surface; but the general form and arrangement of these elevations and depressions, and the scenery they present to a spectator on the lunar surface, are very different from what we behold in our terrestrial landscapes. When we view the moon with a good telescope when about three days old, we perceive a number of elliptical spots with slight shadows, evidently indicating elevations and depressions; we also perceive a number of bright specks or studs in the dark hemisphere, immediately adjacent to the enlightened crescent, and the boundary between the dark and the enlightened portion of the disk appears jagged and uneven. At this time, too, we perceive the dark part of the moon covered with a faint light; so that the whole circular outline of the lunar hemisphere may be plainly discerned. When we take a view of the lunar surface, at the period of half moon, we behold a greater variety of objects, and the shadows of the mountains and caverns appear larger and more prominent. This is, on the whole, the best time for taking a telescopic view of the surface of the moon. When we view her when advanced to a gibbous phase, we see a still greater extent of the surface, but the shadows of the different objects are shorter and less distinct. At the time of full moon, no shadows either of the mountains or caverns are perceptible, but a variety of dark and bright streaks and patches appear distributed in different shapes over all its surface. If we had no other view of the moon but at this period, we should scarcely be able to determine whether mountains and vales existed on this orb. The view of the *full* moon, therefore, however beautiful and variegated, can give us no accurate idea of the mountains, vales, caverns, and other geographical arrangements which diversify its surface.

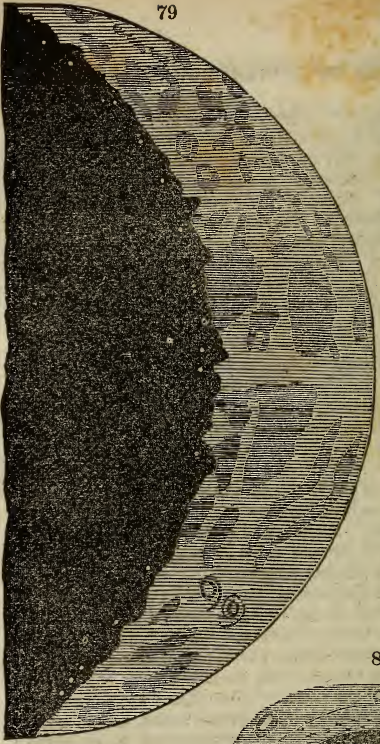
Lunar Mountains.—That the surface of the moon is diversified with mountains, or high elevations, is evident from an inspection of its disk, even with a common telescope. They are recognised from various circumstances. 1. From the appearance of the boundary which separates the dark from the enlightened hemisphere of the moon. This boundary is not a straight line or a regular curve, as it would be if the moon were a perfectly smooth globe, but uniformly presents an uneven or jagged appearance, cut, as it were, into

numerous notches and breaks somewhat resembling the teeth of a saw, which appearance can only be produced by elevations and depressions on the lunar surface (see Fig. LXXIX.) 2. Adjacent to the boundary between light and darkness, and *within* the dark part of the moon, there are seen, in almost every stage of the moon's increase and decrease, a number of *shining points* like stars, completely separated from the enlightened parts, and sometimes other small spaces or streaks which join to the enlightened surface, but run out into the dark side, which gradually change their figure till at length they come wholly within the enlightened boundary. These shining points or streaks are ascertained to be the tops or highest ridges of mountains which the sun first enlightens before his rays can reach the valleys ; just as the beams of the rising sun irradiate our mountain tops before the lower parts of the landscape are enlightened. 3. The *shadows* of the mountains, when they are fully enlightened, are distinctly seen near the border of the illuminated part of the moon, as the shadows of elevated objects are seen on the terrestrial landscape. These shadows are longest and most distinctly marked about the time of half moon ; and they grow shorter as the lunar orb advances to the period of full moon, in the same way as the shadows of terrestrial objects in summer gradually shorten as the sun approaches the meridian. These considerations demonstrate, beyond the possibility of doubt, that mountains of very considerable altitude and in vast variety of forms abound in almost every region of the moon.

The lunar mountains, in general, exhibit an arrangement and an aspect very different from the mountain scenery of our globe. They may be arranged into the four following varieties : 1. *Insulated mountains*, which rise from plains nearly level, like a sugar loaf placed on a table, and which may be supposed to present an appearance somewhat similar to Mount Etna or the peak of Teneriffe. The shadows of these mountains, in certain phases of the moon, are as distinctly perceived as the shadow of an upright staff when placed opposite to the sun ; and their heights can be calculated from the length of their shadows. The heights and the length of the base of more than seventy of these mountains have been calculated by M. Schroeter, who had long surveyed the lunar face with powerful telescopes, and who some time ago published the result of his observations in a work entitled " Frag-

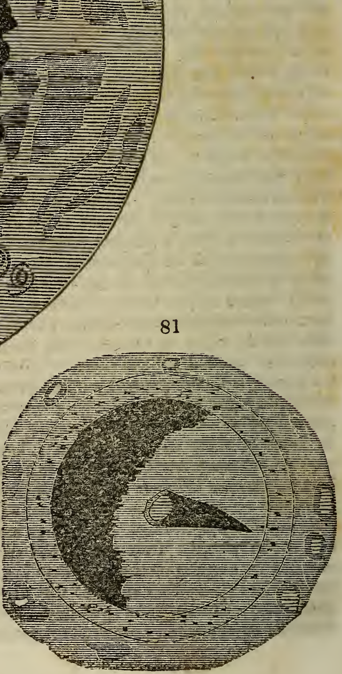
ments of Selenography." Thirty of these insulated mountains are from 2 to 5 miles in perpendicular height; thirteen are above 4 miles; and about forty are from a quarter of a mile to two miles in altitude. The length of their bases varies from 3½ to 96 miles in extent. Some of these mountains will present a very grand and picturesque prospect around the plains in which they stand. 2. *Ranges of mountains*, extending in length two or three hundred miles. These ranges bear a distant resemblance to our Alps, Apennines, and Andes, but they are much less in extent, and do not form a very prominent feature of the lunar surface. Some of them appear very rugged and precipitous, and the highest ranges are, in some places, above four miles in perpendicular altitude. In some instances they run nearly in a straight line from northeast to southwest, as in that range called the *Apennines;* in other cases they assume the form of a semicircle or a crescent. 3. Another class of the lunar mountains is the *circular ranges* which appear on almost every part of the moon's surface, particularly in its southern regions. This is one of the grand peculiarities of the lunar ranges, to which we have nothing similar in our terrestrial arrangements. A plain, and sometimes a large cavity, is surrounded with a circular ridge of mountains, which encompasses it like a mighty rampart. These annular ridges and plains are of all dimensions, from a mile to forty or fifty miles in diameter, and are to be seen in great numbers over every region of the moon's surface. The mountains which form these ridges are of different elevations, from one fifth of a mile to 3½ miles in altitude, and their shadows sometimes cover the one half of the plain. These plains are sometimes on a level with the general surface of the moon, and in other cases they are sunk a mile or more below the level of the ground which surrounds the *exterior* circle of the mountains. In some of these circular ridges I have perceived a narrow *pass* or opening, as if intended to form an easy passage or communication between the interior plain and the regions beyond the exterior of the mountains. 4. The next variety is the *central mountains*, or those which are placed in the middle of circular plains. In many of the plains and cavities surrounded by annular mountains there is an insulated mountain, which rises from the centre of the plain, and whose shadow sometimes extends, in a pyramidal form, across the semidiameter of the plain to the opposite ridges. These central

79

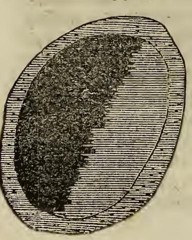


82

81



80



mountains are generally from half a mile to a mile and a half in perpendicular altitude. In some instances they have two and sometimes three separate tops, whose distinct shadows can be easily distinguished. Sometimes they are situated towards one side of the plain or cavity, but, in the great majority of instances, their position is nearly or exactly central. The lengths of their bases vary from five to about fifteen or sixteen miles.

The preceding figures may perhaps convey a rude idea of some of the objects now described; but it is impossible, by any delineations, to convey an idea of the peculiarities and the vast variety of scenery which the lunar surface presents, such as is exhibited by a powerful telescope during the different stages of the increase and decrease of the moon.

Fig. 79 represents the moon in a crescent phase, for the purpose of showing how the enlightened tops of the mountains appear on the dark part of the moon, detached as it were from the enlightened part, and likewise to show how the boundary between the light and darkness appears jagged and uneven, indicating the existence of elevations and depressions upon its surface. Fig. 80 represents a circular or elliptical range of mountains, surrounding a plain of the same shape, where the shadow of that side of the range which is opposite to the sun appears covering the half of the plain. Fig. 81 represents a circular plain, with the shadow of one side of the mountains which encompasses it, and a *central* mountain with its shadow in the same direction. Fig. 82 exhibits another of these circular ridges and plains. Several hundreds of these circular cavities and plains are distributed over the lunar surface, but they are most abundant in the southern regions.

Fig. LXXXIII. exhibits a pretty correct view of the full moon, as seen through a telescope magnifying above a hundred times, in which the darker shades represent, for the most part, the *level* portions of the moon's surface, and the lighter shades those which are more elevated or mountainous. The bright spot near the bottom, from which streaks or streams of light seem to proceed, is called *Tycho* by some, and *Mount Etna* by others. It consists of a large irregular cavity, surrounded by mountains; and the streaks of light are the elevated ridges of ranges of mountains, which seem to converge towards it as to a centre. This is the most variegated and

FIG. LXXXIII.

North.

mountainous region of the lunar surface. Fig. LXXXIV. is a view of the moon, hastily taken, when in a gibbous phase. The shadows were then comparatively short, and it would require to be engraved on a much more extensive scale than our page admits to show distinctly the elevations and depressions at the boundary between light and darkness. Fig. LXXXV. (Nos. 1 and 2) represent some detached spots near the line which separated the dark and enlightened parts of the moon.

From what has been now stated respecting the lunar mountains, it will evidently appear that there must be a great variety of sublime and picturesque scenery connected with the various landscapes of the moon. If the surface of that orb be adorned with a diversity of colour, and with something analo-

FIG. LXXXIV.

FIG. LXXXV. (No. 1.) FIG. LXXXV. (No. 2.)

gous to the vegetation of our globe, there must be presented to the view of a spectator in the moon a variety of scenes altogether dissimilar to those which we can contemplate on

this earth. The circular plains and mountains will present three or four varieties of prospect, of which we have no examples on our globe. In the first place, a spectator near the middle of the plain will behold his view bounded on every hand by a chain of lofty mountains, at the distance of 5, 10, 15, or 20 miles, according to the diameter of the plain; and as the tops of these mountains are at different elevations, they will exhibit a *variety* of mountain scenery. In the next place, when standing on the top of the central mountain, the whole plain, with its diversified objects, will be open to his view, which will likewise take in all the variety of objects connected with the circular mountain-range which bounds his prospect. A third variety of view will be presented in travelling round the plain, where the various aspects of the central mountain will present, at every stage, a new landscape and a diversity of prospect. Another view, still more extensive, will be obtained by ascending to the summit of the circular range, where the whole plain and its central mountain will be full in view, and a prospect will, at the same time, be opened of a portion of those regions which lie beyond the *exterior* boundary of the mountains (see Fig. LXXXI.) A diversity of scenery will likewise be presented by the *shadows* of the circular range and the central mountain. When the sun is in the horizon, the whole plain will be enveloped in the shadows of the mountains, even after daylight begins to appear. These shadows will grow shorter and shorter as the sun rises in the heavens; but a space of time equal to one or two of our days will intervene before the body of the sun is seen from the opposite side of the plain, rising above the mountain tops; and a still longer space of time before his direct rays are seen at the opposite extremity. These shadows are continually varying; during the increase of the moon they are thrown in one direction, and during the decrease in a direction exactly opposite; and it is only about the time of full moon that every part of the plain, and the mountains which surround it, are fully enlightened, and the shadows disappear. There must, therefore, be a far greater variety of sublime mountain-scenery, and of picturesque objects connected with it, on the lunar surface, than what is presented to our view in terrestrial landscapes.

The Lunar Caverns.—These form a very peculiar and prominent feature of the moon's surface, and are to be seen

throughout almost every region; but are most numerous in the southwest part of the moon. Nearly a hundred of them, great and small, may be distinguished in that quarter. They are all nearly of a circular shape, and appear like a very shallow egg-cup. The smaller cavities appear within almost like a hollow cone, with the sides tapering towards the centre; but the larger ones have, for the most part, flat bottoms, from the centre of which there frequently rises a small steep conical hill, which gives them a resemblance to the annular ridges and central mountains above described. In some instances their margins are level with the general surface of the moon, but in most cases they are encircled with a high annular ridge of mountains marked with lofty peaks. Some of the larger of these cavities contain smaller cavities of the same kind and form, particularly in their sides. The mountainous ridges which surround these cavities reflect the greatest quantity of light; and hence that region of the moon in which they abound appears brighter than any other. From their lying in every possible direction, they appear, at and near the time of full moon, like a number of brilliant streaks or radiations. These radiations appear to converge towards a large brilliant spot surrounded by a faint shade, near the lower part of the moon, which is known by the name of *Tycho*, and which every one who views the full moon, even with a common telescope, may easily distinguish. In regard to their *dimensions*, they are of all sizes, from three miles to fifty miles *in diameter* at the top; and their depth below the general level of the lunar surface varies from one third of a mile to three miles and a half. Twelve of these cavities, as measured by Schroeter, were found to be above two miles in perpendicular depth. These cavities constitute a *peculiar feature* in the scenery of the moon, and in her physical constitution, which bears scarcely any analogy to what we observe in the physical arrangements of our globe. But, however different such arrangements may appear from what we see around us in the landscapes of the earth, and however unlikely it may at first sight appear that such places should be the abode of intelligent beings, I have no doubt that, in point of beauty, variety, and sub limity, these spacious hollows, with all their assemblage of circular and central mountain-scenery, will exceed in interest and grandeur any individual scene we can contemplate on our globe. We have only to conceive that such places are di-

versified and adorned with all the vegetable scenery which we reckon beautiful and picturesque in a terrestrial landscape, and with objects which are calculated to reflect with brilliancy the solar rays, in order to give us an idea of the grandeur of the scene. And that the objects connected with these hollows are formed of substances fitted to reflect the rays of the sun with peculiar lustre, appears from the brilliancy which most of them exhibit when either partially or wholly enlightened; presenting to view, especially at full moon, the most luminous portions of the lunar surface, so that former astronomers were led to compare them to rocks of diamond.

Whether there be any evidence of Volcanoes in the Moon.—From a consideration of the broken and irregular ground, and the deep caverns which appear in different parts of the moon's surface, several astronomers were led to conjecture that such irregularities were of volcanic origin. These conjectures were supposed to be confirmed by the appearance of certain luminous points, which were occasionally seen on the dark part of the moon. During the annular eclipse of the sun on the 24th of June, 1778, Don Ulloa perceived, near the northwest limb of the moon, a bright white spot, which he imagined to be the light of the sun shining through an opening in the moon. This phenomenon continued about a minute and a quarter, and was noticed by three different observers. Beccaria observed a similar spot in 1772. M. Bode, of Berlin, M. de Villeneuve, M. Nouet, Captain Kater, and several others, at different times, observed similar phenomena, some of which had the appearance of a small nebula, or a star of the sixth magnitude, upon the dark part of the lunar disk. Sir W. Herschel, in 1787, observed similar phenomena, which he ascribes to the eruption of volcanoes. The following is an extract from his account of those phenomena: "April 19, 1787, $10^h\ 36'$. I perceive three volcanoes in different places of the dark part of the new moon. Two of them are already nearly extinct, or otherwise in a state of going to break out; the third shows an eruption of fire or luminous matter. The distance of the crater from the northern limb of the moon is $3'\ 57''$; its light is much brighter than the nucleus of the comet which M. Mechain discovered at Paris on the 10th of this month." "April 20, 10^h. The volcano burns with greater violence than last night; its diameter cannot be less than three seconds; and hence the shining or burning matter

must be above three miles in diameter. The appearance resembles a small piece of burning charcoal when it is covered by a very thin coat of white ashes, and it has a degree of brightness about as strong as that with which such a coal would be seen to glow in faint daylight."

Such are some of the phenomena from which it has been concluded that volcanoes exist in the moon. That such appearances indicate the existence of fire or some species of luminosity on the lunar surface, is readily admitted; but they by no means prove that anything similar to terrestrial volcanoes exists in that orb. We err egregiously when we suppose that the arrangements of other worlds must be similar to those on our globe, especially when we perceive the surface of the moon arranged in a manner so very different from that of the earth. We have no right to conclude that burning mountains abound in the moon because these are the only large streams of fire that occasionally burst forth from certain points on our globe. For there are many other causes of which we are ignorant, and which may be peculiar to the moon, which may produce the occasional gleams or illuminations to which we allude. The conflagration of a large forest, such as happened a few years ago at Miramichi, the blazing of large tracts of burning heath, the illumination of a large town, or the conflagration of such a city as Moscow, would, in all probability, present to a spectator in the moon luminous specks such as those which astronomers have observed on the dark portion of the lunar orb. Such luminosities in the moon may possibly be of a phosphoric nature, or a mere display of some brilliant artificial scenery by the inhabitants of that planet. Schroeter is of opinion that most of these appearances are to be ascribed to the light reflected from the earth to the dark part of the moon's disk, which returns it from the tops of the mountains under various angles, and with different degrees of brightness; and from various observations I have made on the dark portion of the moon, when about two or three days old, and from the degree of brightness with which some of the small spots have frequently appeared, I am disposed to consider this opinion as highly probable.

The existence of volcanoes on our globe is scarcely to be considered as a part of its original constitution. Such appalling and destructive agents appear altogether inconsistent with the state of an innocent being formed after the Divine

image; and, therefore, we have no reason to believe that they existed in the primitive age of the world, while man remained in his paradisiacal state, but began to operate only after the period of the universal deluge, when the primitive constitution of our globe was altered and deranged, and when earthquakes, storms, and tempests began, at the same time, to exert their destructive energies. They are thus to be considered as an evidence or indication that man is no longer in a state of moral perfection, and that his habitation now corresponds with his character as a sinner. To suppose, therefore, that such destructive agents exist in the moon, would be virtually to admit that the inhabitants of that planet are in the same depraved condition as the inhabitants of this world. The same thing may be said with regard to a pretended discovery which was announced some years ago, that "there are *fortifications* in the moon;" for, if such objects really existed, it would be a plain proof that the inhabitants were engaged in wars and contentions, and animated with the same diabolical principles of pride, ambition, and revenge which have ravaged our globe and demoralized its inhabitants.

Whether there be Seas in the Moon is a question which has engaged the attention of astronomers, and which demands a few remarks. When we view the moon through a good telescope, we perceive a number of large dark spots of different dimensions, some of which are visible to the naked eye. These spots, in the early observations of the moon with telescopes, were generally supposed to be large collections of water similar to our seas, and the names given them by Hevelius, such as *Mare Crisium*, *Mare Imbrium*, &c., are founded on this opinion. The general smoothness of these obscure regions, and the consideration that water reflects less light than the land, induced some astronomers to draw this conclusion. But there appears no solid ground for entertaining such an opinion; for, in the first place, when these dark spots are viewed with good telescopes, they are found to contain numbers of cavities, whose shadows are distinctly perceived falling within them, which can never happen in a sea or smooth liquid body; and besides, several insulated mountains, whose shadows are quite perceptible, are found here and there in these supposed seas. In the next place, when the boundary of light and darkness passes through these spots, it is not exactly a straight line or a

regular curve, as it ought to be were those parts perfectly level like a sheet of water, but appears slightly jagged or uneven. I have inspected these spots hundreds of times, with powers of 150, 180, and 230 times, and in every instance, and in every stage of the moon's increase and decrease, gentle elevations and depressions were seen, similar to the wavings or inequalities which are perceived upon a plain or country generally level. There are scarcely any parts of these spots in which slight elevations may not be seen. In many of them the light and shade, indicating inequality of surface, are quite perceptible; and in certain parts ridges nearly parallel, of slight elevation, with interjacent plains, are distinctly visible. These dark spots, therefore, must be considered as *extensive plains* diversified with gentle elevations and depressions, and consisting of substances calculated to reflect the light of the sun with *a less degree of intensity* than the other parts of the lunar surface. These plains are of different dimensions, from 40 or 50 to 700 miles in extent, and they occupy more than one third of that hemisphere of the moon which is seen from the earth, and, consequently, will contain nearly three millions of square miles. As the moon, therefore, is diversified with mountains and cavities of forms altogether different from those of our globe, so the plains upon the surface of that orb are far more varied and extensive than the generality of plains which are found on the surface of the earth. It is a globe diversified with an immense variety of mountain scenery, and, at the same time, abounding with plains and valleys of vast extent. But there appear to be no seas, oceans, or any *large* collections of water, though it is possible that small lakes or rivers may exist on certain parts of its surface. As we see only one side of the moon from the earth, we cannot tell what objects or arrangements may exist on its opposite hemisphere, though it is probable that that hemisphere does not differ *materially* in its scenery and arrangements from those which are seen on the side which is turned towards the earth.

Atmosphere of the Moon.—Whether the moon has an atmosphere, or body of air similar to that which surrounds the earth, has been a subject of dispute among astronomers. On the one side, the existence of such an atmosphere is denied, because the stars which disappear behind the body of the moon retain their full lustre till they seem to touch its very

edge, and then they vanish in a moment; which phenomenon, it is supposed, would not happen if the moon were encompassed with an atmosphere. On the other hand, it has been maintained that the phenomena frequently attending eclipses of the sun furnish arguments for the existence of a lunar atmosphere. It has been observed on different occasions that the moon in a solar eclipse was surrounded with a luminous ring, which was most brilliant on the side nearest the moon; that the sharp horns of the lunar crescent have been seen blunted at their extremities during total darkness; that, preceding the emersion, a long narrow streak of dusky red light has been seen to colour the western limb of the moon; and that the circular figure of Jupiter, Saturn, and the fixed stars has been seen changed into an elliptical one when they approached either the dark or the enlightened limb of the moon; all which circumstances are considered as indications of a lunar atmosphere. The celebrated M. Schroeter, of Lilienthal, made numerous observations in order to determine this question, and many respectable astronomers are of opinion that his observations clearly prove the existence of an atmosphere around the moon. He discovered near the moon's cusps a faint gray light of a pyramidal form, extending from both cusps into the dark hemisphere, which, being the moon's twilight, must necessarily arise from its atmosphere. It would be too tedious to detail all the observations of Schroeter on this point; but the following are the general conclusions: "That the inferior or more dense part of the moon's atmosphere is not more than 1500 English feet high; and that the height of the atmosphere where it could affect the brightness of a fixed star, or inflect the solar rays, does not exceed 5742 feet," or little more than an English mile. A fixed star will pass over this space in less than two seconds of time; and if it emerge at a part of the moon's limb where there is a ridge of mountains, scarcely any obscuration can be perceptible.

On the whole, it appears most probable that the moon is surrounded with a fluid which serves the purpose of an atmosphere, although this atmosphere, as to its nature, composition, and refractive power, may be very different from the atmosphere which surrounds the earth. It forms no proof that the moon or any of the planets is destitute of an atmosphere because its constitution, its density, and its power of

refracting the rays of light are different from ours. An atmosphere may surround a planetary body, and yet its parts be so fine and transparent that the rays of light from a star or any other body may pass through it without being in the least obscured or changing their direction. In our reasonings on this subject we too frequently proceed on the false principle that everything connected with other worlds must bear a resemblance to those on the earth. But as we have seen that the surface of the moon, in respect to its mountains, caverns, and plains, is very differently arranged from what appears on the landscape of our globe, so we have every reason to conclude that the atmosphere with which that orb may be surrounded is materially different in its constitution and properties from that body of air in which we move and breathe; and it is highly probable, from the diversity of arrangements which exists throughout the planetary system, that the atmospheres of all the planets are variously constructed, and have properties different from each other. Whatever may be the nature of the moon's atmosphere, it is evident that nothing similar to *clouds* exists in it, otherwise they would be quite perceptible by the telescope; and hence we may conclude that neither hail, snow, rain, nor tempests disturb its serenity; for all the parts uniformly present a clear, calm, and serene aspect, as if its inhabitants enjoyed a perpetual spring.

Magnitude of the Moon.—The distance of the moon from the earth is determined from its horizontal parallax; and this distance, compared with its *apparent* angular diameter, gives its *real* or linear diameter. The mean horizontal parallax is fifty-seven minutes, thirty-four seconds, and the mean apparent diameter thirty-one minutes, twenty-six seconds. From these *data* it is found that the real diameter of the moon is 2180 miles, which is little more than the one fourth of the diameter of the earth. The real magnitude of the moon, therefore, is only about one forty-ninth part of that of the earth. This is found by dividing the cube of the earth's diameter by the cube of the moon's, and the quotient will express the number of times that the bulk of the earth exceeds that of the moon; for the real bulk of globes is in proportion to the cubes of their diameters. Although the apparent size of the moon appears equal to that of the sun, yet the difference of their real bulk is very great, for it would require more than *sixty-three millions* of globes of the size of the moon to form a globe

equal in magnitude to that of the sun. Its surface, notwithstanding, contains a very considerable area, comprising nearly 15,000,000 of square miles, or about one third of the habitable parts of our globe; and were it as densely peopled as England, it would contain a population amounting to *four thousand two hundred millions*, which is more than five times the population of the earth; so that the moon, although it ranks among the smallest of the celestial bodies, may contain a population of intelligent beings far more numerous, and perhaps far more elevated in the scale of intellect, than the inhabitants of our globe.

Whether it may be possible to discover the inhabitants of the moon is a question which has been sometimes agitated. To such a question I have no hesitation in replying, that it is highly improbable that we shall ever obtain a direct view of any living beings connected with the moon by means of any telescopes which it is in the power of man to construct. The greatest magnifying power which has ever been applied, *with distinctness*, to the moon, does not much exceed a thousand times; that is, makes the objects in the moon appear a thousand times larger and nearer to the naked eye. But even a power of a thousand times represents the objects on the lunar surface at a distance of 240 miles, at which distance no living beings, although they were nearly of the size of a kraken, could be perceived. Even although we could apply a power of ten thousand times, lunar objects would still appear 24 miles distant; and at such a distance no animal, even of the size of an elephant or a whale, could be discerned. Besides, we ought to consider that we have only a *bird's-eye view* of the objects on the moon; and, consequently, supposing any beings resembling man to exist on that orb, we could only perceive the diameter of their heads, as an aeronaut does when he surveys the crowds beneath him from an elevated balloon. Nay, though it were possible to construct a telescope with a power of one hundred thousand times, which would cause the moon to appear as if only two and a half miles distant, it is doubtful if, even with such an instrument, living beings could be perceived. We ought also to consider that nature has set certain limits to the magnifying power of telescopes; for, although we could apply such powers as now stated to any telescope, the vapours and undulations of the atmosphere, and the diurnal motion of the earth, would interpose

a barrier to distinct vision; and as the quantity of light is diminished in proportion to the magnifying power, the loss of light in such high powers would prevent the distinct perception of any object.

But although we can never hope to *see* any of the inhabitants of the moon by any instrument constructed by human ingenuity, yet we may be able *to trace the operations* of sentient or intelligent beings, or those *effects* which indicate the agency of living beings. A navigator who approaches within a certain distance of a small island, although he perceives no human beings upon it, can judge with certainty that it is inhabited if he perceive human habitations, villages, corn-fields, or other traces of cultivation. In like manner, if we could perceive changes or operations in the moon which could be traced to the agency of intelligent beings, we should then obtain demonstrative evidence that such beings exist on that planet; and I have no doubt that it is possible to trace such operations. A telescope which magnifies 1200 times will enable us to perceive, *as a visible point* on the surface of the moon, an object whose diameter is only about 100 yards or 300 feet. Such an object is not larger than many of our public edifices; and, therefore, were any such edifices rearing in the moon, or were a town or city extending its boundaries, or were operations of this description carrying on in a district where no such edifices had previously been erected, such objects and operations might probably be detected by a minute inspection. Were a multitude of living creatures moving from place to place in a body, or were they encamping in an extensive plain like a large army, or like a tribe of Arabs in the desert, and afterward removing, it is possible that such movements might be traced by the difference of shade or colour which such movements would produce. In order to detect such minute objects and operations, it would be requisite that the surface of the moon should be distributed among at least a hundred astronomers, each having a spot or two allotted him as the object of his more particular investigation, and that the observations be continued for a period of at least thirty or forty years, during which time certain changes would probably be perceived, arising either from physical causes or from the operations of living agents. But although no such changes should ever be detected, it would form no proof that the moon is destitute of inhabitants; for, in other worlds, in-

telligent beings may probably enjoy all the happiness congenial to their natures without those edifices or artificial accommodations which are requisite for man in this terrestrial abode. In reference to the subject under consideration, Dr. Olbers is fully of opinion "that the moon is inhabited by rational creatures, and that its surface is more or less covered with a vegetation not very dissimilar to that of our own earth." Gruithuisen maintains that he has discovered, by means of his large achromatic telescope, "great artificial works in the moon, erected by the lunarians." And lately, another foreign observer maintains, from actual observation, "that great edifices do exist in the moon." I am of opinion that all such announcements are premature and uncertain. Without calling in question the accuracy of the descriptions published by these astronomers, there is some reason to suspect that what they have taken for "edifices" and "artificial works" are only small portions of natural scenery, of which an immense variety, in every shape, is to be found on the surface of the moon. Future and more minute observations may, however, enable us to form a definite opinion on this subject.*

* A short time ago a *hoax* was attempted to be played off on the public in relation to this subject. An article entitled "Wonderful Discoveries in the Moon, by Sir John Herschel," was copied into most of the American, French, and British newspapers and other periodicals, and was likewise published in a separate pamphlet. It is not a little astonishing how easily the public is gulled by such extravagant descriptions as were contained in this pamphlet, and it shows the *ignorance* which still prevails among the great mass of the community in every country in relation to astronomy and optics, that such pretended discoveries should have been listened to even for a moment. For even some editors of newspapers treated the affair in a grave manner, and only expressed their *doubts* on the subject, plainly indicating that they had far less knowledge of the science of astronomy than many schoolboys now acquire. The title of the pamphlet was sufficient to convince any man of common understanding, who directed his attention for a moment to the subject, that the whole was a piece of deception; for it stated that "the object-glass weighed *seven tons*," and had "a magnifying power of 42,000 times." Now, supposing such a power had been used, the objects on the surface of the moon would still have appeared more than five miles and two thirds distant; and how could an animal, even of the largest size, be seen at such a distance? Yet the writer of the pamphlet declares that animals such as sheep, and cranes, and small birds were not only distinguished, but the shape and colour of their horns, eyes, beard, and the difference of sexes, were perceived. To perceive such objects it was requisite that they should have been brought within six yards instead of six miles. The author might have rendered his description more consistent by putting a power of 300,000 times upon his ima-

It has sometimes been a subject of speculation whether it might be possible, by any symbols, to correspond with the inhabitants of the moon. "Gruithuisen, in a conversation with the great continental astronomer Gauss, after describing the regular figures he had discovered in the moon, spoke of the possibility of a correspondence with the lunar inhabitants. He brought to Gauss's recollection the idea he had communicated many years ago to Zimmerman. Gauss answered, that the plan of erecting a geometrical figure on the plains of Siberia corresponded with his opinion, because, according to his view, a correspondence with the inhabitants of the moon could only be begun by means of such mathematical contemplations and ideas which we and they must have in common."* Were the inhabitants of the moon to recognise such a figure, erected on an immense scale, as a signal of correspondence, they might perhaps erect a similar one in reply. But it is questionable whether the intention of such a signal would be recognised; and our terrestrial sovereigns are too much engaged in plunder and warfare to think of spending their revenues in so costly an experiment; and, therefore, it is likely that, for ages to come, we shall remain in ignorance of the genius of

ginary telescope, since he had every power at his command, so as to have brought the objects, at least, within the distance of a mile. The author of this deception, I understand, is a young man in the city of New-York, who makes some pretensions to scientific acquirements, and he may perhaps be disposed to congratulate himself on the success of his experiment on the public. But it ought to be remembered that all such attempts to deceive are violations of the laws of the Creator, who is the "God of truth," and who requires "truth in the inward parts;" and, therefore, they who wilfully and deliberately contrive such impositions ought to be ranked in the class of liars and deceivers. The "Law of *Truth*" ought never for a moment to be sported with. On the universal observance of this law depend the happiness of the whole intelligent system and the foundations of the throne of the Eternal. The greatest part of the evils which have afflicted our world have arisen from a violation of this law; and were it to be *universally* violated, the inhabitants of all worlds would be thrown into a state of confusion and misery, and creation transformed into a chaos. Besides, the propagation of such deceptions is evidently injurious to the interests of science. For when untutored minds and the mass of the community detect such impositions, they are apt to call in question the *real* discoveries of science, as if they were only attempts to impose on their credulity. It is to be hoped that the author of the deception to which I have adverted, as he advances in years and in wisdom, will perceive the folly and the immorality of such conduct.

* Edinburgh New Philosophical Journal for October, 1826, p. 390.

the lunar inhabitants. Schemes, however, far more foolish and preposterous than the above have been contrived and acted upon in every age of the world. The millions which are now wasting in the pursuits of mad ambition and destructive warfare might, with far greater propriety, be expended in constructing a large triangle or ellipsis, of many miles in extent, in Siberia or any other country, which might at the same time accommodate thousands of inhabitants who are now roaming the deserts like the beasts of the forest.

Whatever may be the arrangements of the moon or the genius of its inhabitants, we know that it forms a most beautiful and beneficial appendage to our globe. When the sun has descended below the western horizon, the moon lights up her lamp in the azure firmament, and diffuses a mild radiance over the landscape of the world. She pours her lustre on spacious cities and lofty mountains, glittering on the ocean, the lakes, and rivers, and opening a prospect wide as the eye can reach, which would otherwise be involved in the deepest gloom. As the son of Sirach has observed, "She is the beauty of heaven, the glory of the stars, an ornament giving light in the high places of the Lord." She cheers the traveller in his journeys, the shepherd while tending his fleecy charge, and the mariner while conducting his vessel at midnight through the boisterous ocean. She returns to us, during night, a portion of the solar light which we had lost, and diffuses a brilliancy far superior to that which we derive from all the stars of heaven. If we intend to prosecute our journeys after the sun has left our hemisphere, the moon, in her increase, serves as a magnificent lamp to guide our footsteps. If we wish to commence our progress at an early hour in the morning, the moon, in her decrease, diffuses a mild radiance in the east, and enables us to anticipate the dawn; and if we choose to defer our journey till the period of full moon, this celestial lamp enables us to enjoy, as it were, an uninterrupted day of twenty-four hours long. By this means we can either avoid the burning heats of summer, or despatch such business as may be inexpedient during the light of day. While the apparent revolution of the sun marks out the year and the course of the seasons, the revolution of the moon round the heavens marks out our months; and, by regularly changing its figure at the four quarters of its course, subdivides the month into periods of weeks; and thus exhibits to

all the nations of the earth a "watchlight" or signal, which every seven days presents a form entirely new, for marking out the shorter periods of duration. By its nearness to the earth, and the consequent increase of its gravitating power, it produces currents in the atmosphere, which direct the course of the winds and purify the aerial fluid from noxious exhalations; it raises the waters of the ocean, and perpetuates the regular returns of ebb and flow, by which the liquid element is preserved from filth and putrefaction. It extends its sway even over the human frame, and our health and disorders are sometimes partially dependant on its influence. Even its eclipses, and those it produces of the sun, are not without their use. They tend to arouse mankind to the study of astronomy and the wonders of the firmament; they serve to confirm the deductions of chronology, to direct the navigator, and to settle the geographical positions of towns and countries; they assist the astronomer in his celestial investigations, and exhibit an agreeable variety of phenomena in the scenery of the heavens. In short, there are terrestrial scenes presented in moonlight, which, in point of solemnity, grandeur, and picturesque beauty, far surpass in interest, to a poetic imagination, all the brilliancy and splendours of noonday. Hence, in all ages, a moonlight scene has been regarded, by all ranks of men, with feelings of joy and sentiments of admiration. The following description of Homer, translated into English verse by Mr. Pope, has been esteemed one of the finest night-pieces in poetry.

> "Behold the moon, refulgent lamp of night,
> O'er heaven's clear azure spread her sacred light,
> When not a breath disturbs the deep serene,
> And not a cloud o'ercasts the solemn scene;
> Around her throne the vivid planets roll,
> And stars unnumbered gild the glowing pole;
> O'er the dark trees a yellower verdure shed,
> And tip with silver every mountain's head;
> Then shine the vales; the rocks in prospect rise;
> A flood of glory bursts from all the skies.
> The conscious swains, rejoicing in the sight,
> Eye the blue vault, and bless the useful light."

Without the light of the moon, the inhabitants of the polar regions would be for weeks and months immersed in darkness. But the moon, like a kindly visitant, returns at short intervals in the absence of the sun, and cheers them with her

beams for days and weeks together. So that, in this nocturnal luminary, as in all the other arrangements of nature, we behold a display of the paternal care and beneficence of that Almighty Being who ordained "the moon and stars to rule the night," as an evidence of his superabundant goodness, and of "his mercy, which endureth for ever."

II. ON THE SATELLITES OF JUPITER.

There are four moons or satellites attending the planet Jupiter, which revolve around it from west to east, according to the order of the signs, or in the same direction as the moon revolves round the earth and the planets round the sun, They are placed at different distances from the centre of Jupiter; they revolve round it in different periods of time, and they accompany the planet in its twelve years' revolution round the sun, without deviating in the least in their distances from the planet, as the more immediate centre of their motions. These bodies were discovered by Galileo, who first applied the telescope to celestial observations. Three of them were first seen on the night of the 7th of January, 1610, and were at first supposed to be telescopic stars; but by the observations of three or four subsequent evenings, he discovered them to be attendants on the planet Jupiter. On the 13th of the same month he saw the fourth satellite, and continued his observations till March 2, when he sent his drawings of them, and an account of his observations, to his patron, *Cosmo Medici*, Great Duke of Tuscany, in honour of whom he called them the *Medicean stars*. This discovery soon excited the attention of astronomers, and every one hastened with eagerness to view the new celestial wonders. The senators of Venice, who were eminent for their learning, invited Galileo to come to the tower of St. Mark, and in their presence make a trial of his new instruments. He complied with their request, and in a fine night, neither cold nor cloudy, showed them with his instrument the new phenomena which had excited attention; the satellites of Jupiter, the crescent of Venus, the triple appearance of Saturn, and the inequalities on the surface of the moon, which many of the learned refused to admit, because they overthrew the system of the schools and the philosophical notions which had previously prevailed. At this conference with the Venetian senators Galileo demonstrated the truth of

the Copernican system, and showed how all his discoveries had a tendency to prove that the earth is a moving body, and that the sun is the centre of the planetary motions.

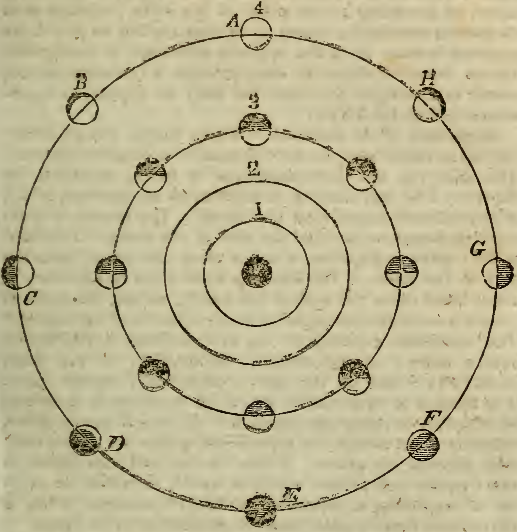
The following are the respective distances of the satellites of Jupiter, in round numbers, and the periodic times in which they revolve around that planet. The mean distance of the first satellite from the centre of Jupiter is 260,000 miles, or somewhat more than the distance of the moon from the earth; and it revolves around the planet in 1 day, 18 hours, 27½ minutes. The second satellite is distant 420,000 miles, and finishes its revolution in 3 days, 13 hours, 13⅔ minutes. The third is distant 670,000 miles, and performs its revolution in 7 days, 3 hours, 42½ minutes. The fourth satellite is distant 1,180,000 miles, or more than four times the distance of the first, and requires 16 days, 16 hours, and 32 minutes to complete its revolution. These satellites suffer numerous eclipses in passing through the shadow of Jupiter, as our moon is eclipsed in passing through the shadow of the earth. But as their orbits are very little inclined to the orbit of Jupiter, their eclipses are much more frequent than those of our moon. The first three satellites are eclipsed every time they are in opposition to the sun. The first satellite is in opposition once in 42½ hours, and, consequently, suffers an eclipse about eighteen times every month. The second suffers eight or nine eclipses, and the third about four eclipses every month. But the fourth satellite frequently passes through its opposition without being involved in the shadow of Jupiter, and, consequently, its eclipses are less frequent than those of the other three, only a few of them happening in the course of a year. As those satellites are opaque globes like our moon—when they are in their inferior conjuction, or in a line between Jupiter and the sun—their bodies are interposed between the sun and certain parts of the disk of the planet, so as to cause an eclipse of the sun to those places over which their shadow passes. These eclipses, or the shadows of the satellites passing across the body of Jupiter, are perceived by powerful telescopes. Sometimes the satellites themselves may be seen crossing the disk like luminous spots; and sometimes the body of the planet interposes between our eye and the satellites, when they are said to suffer an *occultation*. It has been ascertained, by the calculations and investigations of La Place, *that the whole number of these moons can never be eclipsed at*

the same time, and that scarcely ever more than two of them can be eclipsed at once.

The following diagram (Fig. LXXXVI.) exhibits the system of Jupiter's satellites nearly in the proportion of their distances from the planet. The small circles on the orbit of the third satellite represent the enlightened side of the satellites turned towards the sun, and the dark side in an opposite direction. The enlightened side of every satellite is always very nearly turned towards the earth; but in their revolutions round Jupiter they present to that planet all the phases of the moon, as represented in the figures marked on the orbit of the fourth satellite. In the direction *A*, when in opposition to the sun, they appear like *full moons;* in the direction *B* they assume a *gibbous* phase; at *C* they appear like a *half moon;* at *D* like a *crescent;* at *E*, the dark side being turned towards the planet, the satellite becomes invisible; at *F*, *G*, and *H* it again successively appears under a crescent, a half moon, and a gibbous phase. In the direction *A* the satellites are in opposition to the sun, as seen from Jupiter, at which time they pass through his shadow, and are eclipsed for the space of more than two hours, with the exception of the fourth, which sometimes passes the point of its opposition without falling into the shadow. At *E* the shadow of the satellite passes across the disk of Jupiter, producing a solar eclipse to all those regions on his surface over which the shadow moves.

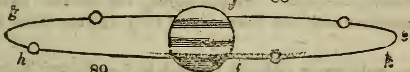
These satellites, when viewed from the earth, do not ap pear to revolve round Jupiter in the manner here represented, but seem to oscillate backward and forward nearly in a straight line. This is owing to our eye being nearly on a level with the plane of their orbits. When the earth is in one of the geocentric nodes of a satellite, the plane of its orbit passes through our eye, and therefore it appears to be a straight line, as *a b* (Fig. LXXXVII.), so that, in passing the half of its orbit which is most distant from the earth, it first seems to move from *b* to *c*, when it is hidden for some time by the planet, and then from *d* to *a*, the point of its greatest elongation; after which it seems to return again in the same line, passing between us and the disk of the planet, till it arrives at its greatest elongation at *b*. In every other situation of the earth, the orbit of a satellite appears as an ellipsis more or less oblong, as represented in Fig. LXXXVIII. When

FIG. LXXXVI.

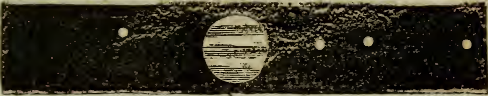


87

88



89



V

it passes through its superior semicircle, or that which is more distant from the earth than Jupiter is, as *e*, *f*, *g*, its motion is *direct*, or according to the order of the signs; when it is in its inferior semicircle, nearer to us than Jupiter, as *h*, *i*, *k*, its apparent motion is in the opposite direction, or *retrograde*. Hence these satellites, as seen through a telescope, appear nearly in a straight line from the body of Jupiter, as represented in Fig. LXXXIX.

Magnitude of the Satellites.—These bodies, though invisible to the naked eye, are nevertheless of a considerable size. The following are their diameters in miles, as stated by Struve. The first satellite is 2508 miles in diameter, which is considerably larger than our moon. The second is 2068 miles in diameter, or about the size of the moon. The third is 3377 miles in diameter, which is more than seven times the bulk of the moon. The fourth is 2890 miles in diameter, or about three times the bulk of the moon; so that the whole of Jupiter's satellites are equal to nearly thirteen of our moons.* The superficial contents of the first satellite is 19,760,865 square miles; of the second, 13,435,442; of the third, 35,827,211; and of the fourth, 26,238,957 square miles. The number of square miles on all the satellites is, therefore, 95,262,475, or more than ninety-five millions of square miles, which is about double the quantity of surface on all the habitable parts of our globe. At the rate of 280 inhabitants to every square mile, these satellites would, therefore, be capable of containing a population of 26,673 *millions*, which is thirty-three times greater than the population of the earth.

The satellites of Jupiter may be seen with a telescope magnifying about thirty times; but in order to perceive their eclipses with advantage, a power of one hundred or one hundred and fifty times is requisite. When the brilliancy of the satellites is examined at different times, it appears to undergo a considerable change. By comparing the mutual positions of the satellites with the times when they acquire their maxi-

* Former astronomers reckoned the bulk of the satellites larger than the dimensions here stated. Cassini and Maraldi reckoned the diameter of the third satellite to be one eighteenth of the diameter of Jupiter, and, consequently, nearly 5000 miles in diameter; and the first and second to be one twentieth of Jupiter's diameter, or about 4450 miles; which estimation would make the magnitudes of these bodies much larger than stated by Struve.

mum of light, Sir W. Herschel concluded that, like the moon, they all turned round their axis in the same time that they performed their revolution round Jupiter. The same conclusion had been deduced by former astronomers in reference to the fourth satellite. This satellite was sometimes observed to take but half the usual time in its entrance on the disk of Jupiter or its exit from it, which was supposed to be owing to its having a dark spot upon it that covered half its diameter; and, by observing the period of its variations, it was concluded that it had a rotation round its axis. These circumstances form a presumptive proof that the surface of these satellites, like our moon, are diversified with objects of different descriptions, and with varieties of light and shade. Cassini suspected the first satellite to have an atmosphere, because the shadow of it could not be seen, when he was sure it should have been, upon the disk of Jupiter, if it had not been shortened by its atmosphere, as is the case in respect to the shadow of the earth in lunar eclipses.

From what has been stated respecting the motions, magnitudes, and eclipses of these satellites, it is evident they will present a most diversified and sublime scenery in the firmament of Jupiter. The first satellite moves along a circumference of 1,633,632 miles in the space of 42½ hours, at the rate of 38,440 miles an hour, which is a motion sixteen times more rapid than that of the moon in its circuit round the earth. During this short period it presents to Jupiter all the appearances of a new moon, crescent, half moon, gibbous phase, and full moon, both in the increase and decrease; so that, in the course of twenty-one hours, it passes through all the phases which our moon exhibits to us; besides suffering an eclipse in passing through the shadow of the planet, and producing either a partial or total eclipse of the sun to certain regions of Jupiter on which its shadow falls. The rapidity of its motion through the heavens will also be very striking; as it will move through the whole hemisphere of the heavens in the course of twenty-one hours, besides its daily apparent motion, in consequence of the diurnal rotation of Jupiter. The other three satellites will exhibit similar phenomena, but in different periods of time. Sometimes two or three of these moons, and sometimes all the four, will be seen shining in the firmament at the same time; one like a crescent, one like a half moon, and another in all its splen-

dour as a full enlightened hemisphere; one entering into an eclipse, another emerging from it; one interposing between the planet and the sun, and for a short time intercepting his rays; one advancing from the eastern horizon, and another setting in the west; one satellite causing the shadows of objects on Jupiter to be thrown in one direction, and another satellite causing them to be projected in another, or in an opposite direction; while the rapid motions of these bodies among the fixed stars will be strikingly perceptible. Eclipses of the satellites and of the sun will be almost an every-day phenomenon, and occultations of the fixed stars will be so frequent and regular as to serve as an accurate measure of time.

The eclipses of Jupiter's satellites afford signals of considerable use for determining the longitude of places on the earth. For this purpose tables of these eclipses, and of the times at which the satellites pass across the disk of Jupiter or behind his body, are calculated and inserted in the nautical and other almanacs. These tables are adapted to the meridian of the Royal Observatory at Greenwich; and by a proper use of them, in connexion with observations of the eclipses, the true meridian, or the distance of a place east or west from Greenwich, may be ascertained. For example: suppose, on the 27th of December, 1837, the immersion of Jupiter's first satellite be observed to happen, in an unknown meridian, at 15 hours, 23 minutes, 10 seconds, I find by the tables that this immersion will happen at Greenwich at 13 hours, 34 minutes, 50 seconds of the same day. The difference of the time is 1 hour, 48 minutes, 20 seconds, which, being converted into degrees of the equator (allowing 15 degrees for an hour), will make 27 degrees, 5 minutes, which is the longitude of the place of observation. This longitude is *east* of Greenwich, because the time of observation was *in advance* of the time at the British observatory. Had the time of observation been behind that of Greenwich, for example, at 13 hours, 4 minutes, 50 seconds, the place must then have been 7½ degrees west of the Royal Observatory. *Before* Jupiter's opposition to the sun, or when he passes the meridian in the morning, the shadow is situated to the *west* of the planet, and the *immersions* happen on that side; but *after* the opposition the *emersions* happen to the *east*. These eclipses cannot be observed with advantage unless Jupiter be

eight degrees *above*, and the sun at least eight degress *below* the horizon.

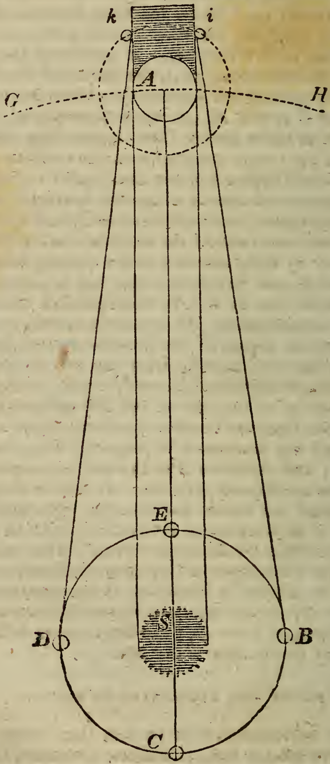
The eclipses of Jupiter's moons first suggested the idea of *the motion of light*. As the orbit of the earth is concentric with that of Jupiter, the mutual distance of these two bodies is continually varying. In the following figure let S represent the sun; B, C, D, E, the orbit of the earth; and G, H, a portion of the orbit of Jupiter. It is evident that when the earth is at E and Jupiter at A, the earth will be the semidiameter of its orbit nearer Jupiter than when it is at B or D; and when at C it will be the whole diameter of its orbit, or 190,000,000 of miles farther from Jupiter than when it is at E. Now if light were instantaneous, the satellite i, to a spectator at B, would appear to enter into Jupiter's shadow, k i, at the same moment of time as to another spectator at E. But, from numerous observations, it was found, that when the earth was at E, the immersion of the satellite into the shadow happened sooner by eight minutes and a quarter than when the earth was at B, and sixteen minutes and a half sooner than when the earth was at C. It was therefore concluded that light is not instantaneous, but requires a certain space of time to pass from one region of the universe to another, and that the time it takes in passing from the sun to the earth, or across the semidiameter of the earth's orbit, is eight minutes and a quarter, or at the rate of 192,000 miles every second, which is more than ten hundred thousand times swifter than a cannon ball the moment it is projected from the mouth of the cannon; and therefore it is the swiftest movement with which we are acquainted in nature. It follows that, if the sun was annihilated, we should see him for eight minutes afterward; and if he were again created, it would be eight minutes before his light would be perceived. The motion of light deduced from the eclipses of Jupiter's satellites has been confirmed by Dr. Bradley's discovery of the *aberration of light* produced by the annual motion of the earth, from which it appears that the light from the fixed stars moves with about the same velocity as the light of the sun.

III. ON THE SATELLITES OF SATURN.

Saturn is surrounded with no less than seven satellites, which revolve around him, at different distances, in a manner

similar to those of Jupiter. As they are more difficult to be perceived than the satellites of Jupiter, owing to the great distance of Saturn from the earth, none of them were discov-

Fig. XC.



ered till the telescope was considerably improved; and more than a century intervened after the first five satellites till the sixth and seventh were detected. As was to be supposed, the larger satellites were first discovered. In the year 1665, about forty-five years after the invention of the telescope, M. Huygens, a celebrated Dutch mathematician and astronomer, discovered the fourth satellite, which is the largest, with a telescope twelve feet long. Four of the others were discovered by Cassini; the fifth in 1671, which is next in brightness to the fourth; the third in December, 1672; and the first and second in the month of March, 1684. These four satellites were first observed by common refracting telescopes of 100 and 136 feet in length; but, after being acquainted with them, he could see them all, in a clear sky, with a tube of thirty-four feet. The sixth and seventh satellites were discovered by Sir W. Herschel in August, 1789, soon after his large forty-feet reflecting telescope was completed. These are nearer to Saturn than the other five; but, to avoid confusion, they are named in the order of their discovery. The following is the order of the satellites in respect of their distance from Saturn:—

Seventh.	Sixth.	First.	Second.	Third.	Fourth.	Fifth.
1	2	3	4	5	6	7

The motions and distances of these bodies have not been so accurately ascertained as those of Jupiter. The following statement contains a near approximation of their periods and distances. The seventh satellite, or that nearest to Saturn, is distant 120,000 miles from the centre of the planet, about 80,000 from its surface, and only about 18,000 miles beyond the edge of the outer ring. It moves round the planet in twenty-two hours, thirty-seven minutes, a circuit of 377,000 miles, at the rate of 16,755 miles an hour. The sixth satellite, or the second from Saturn, is distant 150,000 miles, and finishes its revolution in one day, eight hours, fifty-three minutes. The first of the old satellites, or the third from Saturn, finishes its periodical revolution in one day, twenty-one hours, eighteen minutes, at the distance of 190,000 miles. The second (or fourth from Saturn), in two days, seventeen hours, forty-four and three quarter minutes, at the distance of 243,000 miles The third (fifth from Saturn), in four days, twelve hours, fifty five minutes, at the distance of 340,000 miles. The fourth (sixth from Saturn), in fifteen days, twenty-two hours fifty

one minutes, at the distance of 788,000 miles. The fifth (seventh from Saturn), in seventy-nine days, seven hours, and fifty-four and a half minutes, at the distance of 2,297,000 miles.

The orbits of the six inner satellites are inclined about 30 degrees to the plane of Saturn's orbit, and lie almost exactly in the plane of the rings, and therefore they appear to move in ellipses similar to the ellipses of the rings. But the orbit of the fifth or outer satellite makes an angle with the plane of Saturn's orbit of 24 degrees, 45 minutes. These satellites, having their orbits inclined at so great angles to Saturn, cannot cross the body of that planet, or go behind it, or pass through its shadow, as Jupiter's satellites do, except on rare occasions, and hence they very seldom suffer eclipses or occultations. The only time when eclipses happen is near the periods when the ring is seen edgewise. The fifth or most distant satellite is sometimes invisible in the eastern part of its orbit, which is supposed to arise from one part of the satellite being less luminous than the rest. Sir W. Herschel observed this satellite through all the variations of its light, and concluded, as Cassini had done before, that it turned round its axis like our moon, in the same time that it performed its revolution round Saturn. In consequence of this rotation, the obscure part of its disk is turned towards the earth when in the part of its orbit east of Saturn; and the luminous portion of its surface is turned to the earth and becomes visible while it passes through the western part of its course.

Of these satellites the two innermost are the smallest and the most difficult to be perceived. They have never been discerned but with the most powerful telescopes, and then under peculiar circumstances. At the time of the disappearance of the ring, "they have been seen threading, like beads, the most infinitely thin fibre of light to which it is then reduced, and, for a short time, advancing off it at either end." Few astronomers besides Sir W. Herschel and his son have been able to detect these small bodies. The celebrated Schroeter and Dr. Harding, on the 17th, 20th, 21st, and 27th of February, 1798, obtained several views of the sixth satellite (the second from Saturn) by means of a reflecting telescope 13 feet long, carrying a power of 288. Their observations fully confirmed the accuracy of Sir W. Herschel's statement of the period of its revolution. The first and second satellites (third

and fourth from Saturn) are the next smallest; the third (fifth from Saturn) is greater than the first and second; the fourth (sixth from Saturn), the most conspicuous and the most distant satellite, according to Sir John Herschel, is by far the largest, although it is not so conspicuous in one part of its orbit. In order to see any of the satellites of this planet, a good telescope, with a power of at least 70 or 80 times, is requisite, and with such a power only the two outermost satellites will be perceived. To perceive all the five old satellites requires a power of at least 200 times, and a considerable quantity of light.

Magnitude of Saturn's Satellites.—The precise bulk of these satellites has not yet been accurately determined. Sir John Herschel estimates the most distant satellite, which he thinks the largest, as not much inferior in size to the planet Mars, which is 4200 miles in diameter. The fourth satellite, which is the most conspicuous, cannot be supposed to be much inferior to it in bulk. But as the precise dimensions of most of the inner satellites cannot be estimated with accuracy, we shall not, perhaps, exceed the dimensions of these bodies if we suppose for the whole a general average of 3000 miles diameter for each. On this assumption, the surface of each satellite will contain 28,274,400 of square miles, which is nearly double the area of our moon. The area of all the seven satellites will therefore amount to 197,920,800 square miles, which is four times the quantity of surface on all the habitable parts of the earth. At the rate of 280 inhabitants to the square mile, these satellites would therefore contain 55,417,824,000, or more than *fifty-five thousand millions* of inhabitants, which is sixty-nine times the population of our globe.

These satellites will present a beautiful and variegated appearance in the firmament of Saturn; the nearest satellite, being only 80,000 miles from the *surface* of the planet, which is only the one third of the distance of the moon from the earth, will exhibit a very large and splendid appearance. Supposing it to be only about the diameter of our moon, it will present a surface nearly nine times larger than the moon does to us; and in the course of twenty-two and a half hours will exhibit all the phases of a crescent, half moon, full moon, &c., which the moon presents to us in the course of a month; so that almost every hour its phase will be sensibly changed,

and its motion round the heavens will appear exceedingly rapid. While, in consequence of the diurnal rotation of Saturn, it will appear to move from east to west, it will also be seen moving with a rapid velocity among the stars in a contrary direction, and will pass over a whole hemisphere of the heavens in the course of eleven hours. The next satellite in order from Saturn, being only 110,000 miles from his surface, will also present a splendid appearance, much larger than our moon, and will exhibit all the phases of the moon in the course of sixteen hours. All the other satellites will exhibit somewhat similar phenomena, but in different periods of time. They will appear, when viewed from the surface of Saturn, of different sizes; some of them nine times larger than the moon appears to us, some three times, some double the size, and it is probable that even the most distant satellites will appear nearly as large as our moon, so that a most beautiful and sublime variety of celestial phenomena will be presented to a spectator in the heavens of Saturn, besides the diversified aspects of the rings to which we formerly adverted, all displaying the infinite grandeur and beneficence of the Creator.

IV. ON THE SATELLITES OF URANUS.

This planet is attended by six satellites, all of which were discovered by Sir W. Herschel, to whom we owe the discovery of the planet itself. The second and fourth satellites were detected in January, 1787, about six years after the planet was discovered; the other four were discovered several years afterward, but their distances and periodical revolutions have not been so accurately ascertained as those of the two first discovered.

The *first* of these satellites, or the nearest to Uranus, completes its siderial revolution in 5 days, 21 hours, and 25 minutes, at the distance of 224,000 miles from the centre of the planet. The *second* in 8 days, 17 hours, at the distance of 291,000 miles. The *third* in 10 days, 23 hours, at the distance of 340,000 miles. The *fourth* in 13 days, 11 hours, at the distance of 390,000 miles. The *fifth* in 38 days, 1 hour, 48 minutes, at the distance of 777,000 miles. The *sixth* in 107 days, 16 hours, 40 minutes, at the distance of 1,556,000 miles.

These bodies present to our view some remarkable and unexpected peculiarities. Contrary to the analogy of the whole

planetary system, *the planes of their orbits are nearly perpendicular to the ecliptic*, being inclined no less than 79 degrees to that plane. Their motions in these orbits are likewise found to be *retrograde*, so that, instead of advancing from west to east round Uranus, as all the other planets and satellites do, they move in the opposite direction. Their orbits are quite circular, or very nearly so, and they do not appear to have undergone any material change of inclination since the period of their discovery. "These anomalous peculiarities," says Sir John Herschel, "seem to occur at the extreme limits of the system, as if to prepare us for farther departure from all its analogies in other systems which may yet be disclosed to us" in the remoter regions of space.

The satellites of Uranus are the most difficult objects to perceive of any within the boundary of the planetary system, excepting the two interior satellites of Saturn ; and therefore few observers, excepting Sir William and Sir John Herschel, have obtained a view of them. Their magnitudes, of course, have never been precisely determined ; but there is every reason to believe that they are, on an average, as large as the satellites of Saturn, if not larger, otherwise they could not be perceived at the immense distance at which they are placed from our globe. Supposing them, on an average, to be 3000 miles in diameter—and they can scarcely be conceived to be less—the surfaces of all the six satellites will contain 169,646,400 square miles, or about 3½ times the area of all the habitable portions of the earth ; and which, at the rate formerly stated, would afford scope for a population of 47,500,992,000, or above forty-seven thousand millions, which is about sixty times the present number of the inhabitants of the earth.

The satellites of Uranus seldom suffer eclipses ; but as the plane in which they move must pass twice in the year through the sun, there may be eclipses of them at those times ; but they can be seen only when the planet is near its opposition. Some eclipses were visible in 1799 and 1818, when they appeared to ascend through the shadow of the planet in a direction almost perpendicular to the plane of its orbit. It is probable that this planet is attended with more satellites than those which have yet been discovered. It is not unlikely that two satellites at least revolve between the body of the planet and the first satellite ; for the third satellite of Saturn is not nearly so far distant from the surface of that planet as the first

satellite of Uranus is from its centre. But as the inner satellites may be supposed to be the smallest, and yet present as large a surface to the planet as the exterior ones, it is probable that, on account of their diminutive size, they may never be detected. It is likewise not improbable that two satellites may exist in the large spaces which intervene between the orbits of the fourth and fifth, and the fifth and sixth satellites. All these satellites will not only pour a flood of light on this distant planet, but will exhibit a splendid and variegated appearance in its nocturnal firmament.

The satellites of Jupiter, Saturn, and Uranus, of which we have given a brief description in the preceding pages, form, as it were, so many distinct planetary systems in connexion with the great system of the sun. The same laws of motion and gravitation which apply to the primary planets are also applicable to the secondary planets or moons. The squares of their periodical times are in proportion to the cubes of their distances. They are subject to the attraction of their primaries, as all the primary planets are attracted by the sun; and as the sun, in all probability, is carried round a distant centre along with all his attendants, so the satellites are carried round the sun along with their respective planets; partly by the influence of these planets, and partly by the attractive power of the great central luminary. Each of these secondary systems forms a system by itself, far more grand and extensive than the whole planetary system was conceived to be in former times. Even the system of Saturn itself, including its rings and satellites, contains a mass of matter more than a thousand times larger than the earth and moon. The system of Jupiter comprises a mass of matter nearly fifteen hundred times the size of these two bodies; and even that of Uranus is more than eighty times the dimensions of our terrestrial system.

CHAPTER V.

ON THE PERFECTIONS OF THE DEITY, AS DISPLAYED IN THE PLANETARY SYSTEM.

ALL the works of nature speak of their Author in language which can scarcely be misunderstood. They proclaim the existence of an original, uncreated Cause, of an eternal Power and Intelligence, and of a supreme agency which no created being can control. "The heavens" in a particular manner "declare the glory of God, and the firmament showeth forth his handiwork." When we consider the heavenly orbs in their size, their distance, the rapidity of their motions, and the regularity and harmony with which they perform their respective revolutions, it is obvious to the least attentive observer that such bodies could not have formed themselves, or have arranged their motions, their periods, and their laws in the beautiful order in which we now behold them. Motion of every kind supposes a moving power. As matter could not make itself, so neither can it set itself in motion. Its motion must commence from a power exterior to itself, and that power must correspond in energy to the *effect* produced. In the planetary system we find bodies a thousand times larger than the earth moving with a velocity sixty times greater than a cannon ball, and carrying along with them in their train other expansive globes in the same swift career. Such motions could only proceed from a power which is beyond calculation or human comprehension; and such a power can only reside in an uncreated, self-existent, and independent Intelligence. The *continuance* of such motions must likewise depend upon the incessant agency of the same Almighty Being, either directly, or through the medium of such subordinate agents as he is pleased to appoint for the accomplishment of his designs. In this respect the laws of motion, of attraction, gravitation, electricity, and other powers, are so many agents under the direction and control of the Almighty for carrying forward the plans of his physical and moral government of the universe

The study of astronomy ought always to have in view as its ultimate object, to trace the Divine perfections as displayed in the phenomena of the heavens. For, as our poet Milton expresses it, "Heaven is as the book of God before us set, wherein to read his wondrous works." There is no scene we can contemplate in which the attributes of the Divinity are so magnificently displayed. It is in the heavens alone that we perceive a sensible evidence of the *infinity* of his perfections, of the grandeur of his operations, and of the immeasurable extent of his universal dominions. Even the planetary system, small as it is in comparison of the whole extent of creation, contains within it wonders of creating Omnipotence and skill which almost overpower the human faculties, and demonstrate the "eternal power and godhead" of Him who at first brought it into existence. To consider astronomy merely as a secular branch of knowledge, which improves navigation, and gives scope to the mathematician's skill, and to overlook the demonstrations it affords of the invisible Divinity, would be to sink this noble study far below its native dignity, and to throw into the shade the most illustrious manifestations of the glories of the Eternal Mind.

When we contemplate the stupendous globes of which the planetary system is composed, and the astonishing velocity with which they run their destined rounds, we cannot but be struck with an impressive idea of the POWER of the Deity; of the incomprehensible ENERGIES of the eternal mind that first launched them into existence. What are all the efforts of puny man as displayed in the machinery he has set in motion, and in the most magnificent structures he has reared, in comparison with worlds a thousand times larger than this earthly ball, and with *forces* which impel them in their courses at the rate of thirty thousand, and even a hundred thousand miles an hour! The mind is overpowered and bewildered when it contemplates such august and magnificent operations. Man, with all his imaginary pomp and greatness, appears, on comparison, as a mere microscopic animalcula, yea, as "less than nothing and vanity;" and such displays of the omnipotence of Jehovah are intended to bring down the "lofty looks of men," and to stain the pride of all human grandeur, "that no flesh should glory in his presence." Without materials, and with out the aid of instruments or machinery, the foundations of the planetary system were laid, and all its arrangements com-

eted. "He only *spake*, and it was done;" he only gave one *command*, and mighty worlds started into existence and run their spacious rounds. "By the word of the Lord were the heavens made, and all the host of them by the breath of his mouth." That Almighty Being who, by a single volition, could produce such stupendous effects, must be capable of effecting what far transcends our limited conceptions. His agency must be universal and uncontrollable, and no created being can ever hope to frustrate the purposes of his will or counteract the designs of his moral government. Whatever he has promised will be performed; whatever he has predicted by his inspired messengers must assuredly be accomplished. "For the kingdom is the Lord's, he is the Governor among the nations," and all events, and the movements of all intelligent beings, are subject to his sovereign control. "Though the mountains should be carried into the midst of the seas, and the earth reel to and fro like a drunkard;" yea, though this spacious globe should be wrapped in flames, and "all that it inherits be dissolved," yet that power which brought into existence the planetary worlds, and has supported them in their rapid career for thousands of years, can cause "new heavens and a new earth, wherein dwelleth righteousness," to arise out of its ruins, and to remain in undiminished beauty and splendour. "The heavens," says an inspired writer, "declare the glory of the Lord, and there is no speech nor language where their voice is not heard." Even the pagan nations were impressed with the power of a supreme intelligence from a contemplation of the nocturnal firmament. "When we behold the heavens," says Cicero, "when we contemplate the celestial bodies, can we fail of conviction? Must we not acknowledge that there is a Divinity, a perfect being, a ruling intelligence that governs, a God who is everywhere, and directs all by his power? Any one who doubts this may as well deny that there is a sun that enlightens us." Plato, when alluding to the motions of the sun and planets, exclaims, "How is it possible for such prodigious masses to be carried round for so long a period by any natural cause? for which reason I assert God to be the great and first cause, and that it is impossible it should be otherwise."

A very slight view of the planetary system is sufficient to impress our minds with an overpowering sense of the *grandeur* and *omnipotence* of the Deity. In one part of it we behold

a globe fourteen hundred times larger than our world flying through the depths of space, and carrying along with it a retinue of revolving worlds in its swift career. In a more distant region of this system we behold another globe, of nearly the same size, surrounded by two magnificent rings, which would enclose 500 worlds as large as ours, winging its flight through the regions of immensity, and conveying along with it seven planetary bodies larger than our moon, and the stupendous arches with which it is encircled, over a circumference of five thousand seven hundred millions of miles. Were we to suppose ourselves placed on the nearest satellite of this planet, and were the satellite supposed to be at rest, we should behold a scene of grandeur altogether overwhelming; a globe filling a great portion of the visible heavens, encircled by its immense rings, and surrounded by its moons, each moving in its distinct sphere and around its axis, and all at the same time flying before us in perfect harmony with the velocity of 22,000 miles an hour. Such a scene would far transcend everything we now behold from our terrestrial sphere, and all the conceptions we can possibly form of motion, of sublimity, and grandeur. Contemplating such an assemblage of magnificent objects moving through the ethereal regions with such astonishing velocity, we would feel the full force of the sentiments of inspiration: "THE LORD GOD OMNIPOTENT REIGNETH. His power is irresistible; his greatness is unsearchable; wonderful things doth he which we cannot comprehend." The *motions* of the bodies which compose this system convey an impressive idea of the agency and the energies of Omnipotence. One of these bodies, eighty times larger than the earth, and the slowest moving orb in the system, is found to move through its expansive orbit at the rate of fifteen thousand miles an hour; another at twenty-nine thousand miles in the same period, although it is more than a thousand times the size of our globe; another at the rate of eighty thousand miles; and a fourth with a velocity of more than a hundred thousand miles every hour, or thirty miles during every beat of our pulse. The mechanical forces requisite to produce such motions surpass the mathematician's skill to estimate or the power of numbers to express. Such astonishing velocities, in bodies of so stupendous a magnitude, though incomprehensible and overwhelming to our limited faculties, exhibit a most convincing demonstration of the existence of an agency

and a power which no created beings can ever counteract, and which no limits can control. Above all, the central body of this system presents to our view an object which is altogether overpowering to human intellects, and of which, in our present state, we shall never be able to form an adequate conception. A luminous globe, thirteen hundred thousand times larger than our world, and five hundred times more capacious than all the planets, satellites, and comets taken together, and this body revolving round its axis and through the regions of space, extending its influences to the remotest spaces of the system, and retaining by its attractive power all the planets in their orbits, is an object which the limited faculties of the human mind, however improved, can never grasp, in all its magnitude and relations, so as to form a full and comprehensive idea of its magnificence. But it displays in a most astonishing manner the GRANDEUR of HIM who launched it into existence, and lighted it up "by the breath of his mouth;" and it exhibits to all intelligences a demonstration of his "eternal power and godhead." So that, although there were no bodies existing in the universe but those of the planetary system, they would afford an evidence of a *power* to which no limits can be assigned; a POWER which is infinite, universal, and uncontrollable.

The planetary system likewise exhibits a display of the *wisdom and intelligence* of the Deity. If it is an evidence of wisdom in an artist that he has arranged all the parts of a machine, and proportioned the movements of its different wheels and pinions so as exactly to accomplish the end intended, then the arrangement of the planetary system affords a bright display of "the manifold wisdom of God." In the *centre* of this system is placed the great source of light and heat; and from no other point could those solar emanations be propagated, in an equable and uniform manner, to the worlds which roll around it. Had the sun been placed at a remote distance from the centre, or near one of the planetary orbits, the planets in one part of their course would have been scorched with the most intense heat, and in another part would have been subjected to all the rigours of excessive cold; their motions would have been deranged, and their present constitution destroyed. The enormous bulk of this central body was likewise requisite to diffuse light and attractive influence throughout every part of the system. The diurnal *rotations* of the planets evince the

same wisdom and intelligence. Were these bodies destitute of diurnal motions, one half of their surface would be parched with perpetual day, and the other half involved in the gloom of a perpetual night. To the inhabitants of one hemisphere the sun would never appear, and to the inhabitants of the other the stars would be invisible; and those expansive regions of the universe, where the magnificence of God is so strikingly displayed, would be for ever veiled from their view. The *permanency* of the axes on which the planets revolve was likewise necessary, in order to the stability of the system and the comfort of its inhabitants; and so we find that their poles point invariably in the same direction or to the same points of the heavens, with only a slight variation scarcely perceptible till after the lapse of centuries. As the planets are of a spheroidal figure, had the direction of their axes been liable to frequent and sudden changes, the most alarming and disastrous catastrophes might have ensued. In such a globe as ours, the shifting of its axis might change the equatorial parts of the earth into the polar, or the polar into the equatorial, to the utter destruction of those plants and animals which are not capable of interchanging their situations. Such a change would likewise cause the seas to abandon their former positions, and to rush to the new equator; the consequence of which would be, that the greater part of the men and animals with which it is now peopled would be again overwhelmed in a general deluge, and the habitable earth reduced to a cheerless desert. But all such disasters are prevented by the permanent position of the axis of our globe and of the other planets during every part of their annual revolutions, as fixed and determined by Him who is "wonderful in counsel and excellent in working."

The same wisdom is conspicuous in so *nicely balancing and proportioning the magnitudes, motions, and distances of the planetary orbs.* We find that the larger planets move in orbits most remote from the smaller planets and from the centre of the system. If the great planets Jupiter and Saturn had moved in lower spheres and at no great distance from the smaller, their attractive force would have had a much more powerful influence than it now has in disturbing the planetary motions, and might have introduced considerable confusion into the system. But, while they revolve at so great distances from all the inferior planets, their influence is

inconsiderable, and the slight perturbations they produce are not permanent, but *periodical;* they come to a limit, and then go back again to the same point as before. Again, *the law of gravitation*, by which the planets are directed in their motions, is also an evidence of Divine intelligence. The law is found to act reciprocally as the square of the distance; that is, at double the distance it has one fourth, and at triple the distance one ninth of the force; at one half the distance it has four times, and at one third the distance it has nine times the strength or influence. Now it could easily be shown, that a law directly opposite to this, or even differing materially from it, would not only derange the harmony of the system, but might be attended with the most disastrous consequences. If, for instance, a planet as large and as remote as Saturn had attracted the earth in proportion to the quantity of matter it contains, and, at the same time, *in any proportion to its distance;* in other words, had its attractive power been greater the farther it was removed from us, it would have dragged our globe out of its course, deranged its motions, and, in all probability, deprived us of the security we now possess, and of all the prospects and enjoyments which depend upon its equable and harmonious movements. There is no contrivance in the system more wonderful than the *rings* of Saturn. That these rings should be separated thirty thousand miles from the body of the planet; that they should, notwithstanding, accompany the planet in its revolution round the sun, preserving invariably the same distance from it; that they should revolve round the planet every ten hours, at the immense velocity of more than a thousand miles in a minute; and that they should never fly off to the distant regions of space, nor fall down upon the planet, are circumstances which require adjustments far more intricate and exquisite than we can conceive, and demonstrate that the almighty contriver of that stupendous appendage to the globe of Saturn is "great in counsel and mighty in operation." Yet these adjustments, in whatever they may consist, have been completely effected. For this planet has been flying through the regions of space in a regular curve for thousands of years, and the system of its satellites and rings still remains permanent and unimpaired as at its first creation.

An evidence of wisdom may likewise be perceived in the *distance* at which each planet is placed from the great central

body of the system. In the case of our own globe, its distance from the sun is so adjusted as to correspond to the density of the earth and waters, to the temper and constitution of the bodies of men and other animals, and to the general state of all things here below. The quantity of light which the central luminary diffuses around us is exactly adapted to the structure of our eyes, to the width of their pupils, and the nervous sensibility of the retina. The heat it produces, by its action on the *caloric* connected with our globe, is of such a temperature as is exactly suited to the nature of the soil and to the constitution of the animal and vegetable tribes. It is placed at such a distance as to enlighten and warm us, and not so near as to dazzle us with its splendour or scorch us with its excessive heat; but to cheer all the tribes of living beings, and to nourish the soil with its kindly warmth. Were the earth removed fifty millions of miles farther from the sun, everything around us would be frozen up, and we should be perpetually shivering amid all the rigours of excessive cold. Were it placed as much nearer, the waters of the rivers and the ocean would be transformed into vapour; the earth would be hardened into an impenetrable crust; the process of vegetation would cease; and all the orders of animated beings would faint under the excessive splendour of the solar beams. There can be no doubt that the distances of the other planets are likewise adapted to the nature of the substances of which they are composed and the constitution of their inhabitants. We find that the *densities* of these bodies *decrease* in proportion to their distance from the sun; and it is highly probable that this is one reason, among others, why they are placed at different distances, and are thus adapted to the greater or less degree of influence which the central luminary may produce on their surfaces.

The *figures* of the planetary bodies likewise indicate contrivance and intelligence. They are all either of a spherical or spheroidal form, and this figure is evidently the best adapted to a habitable world. It is the most *capacious* of all forms, and contains the greatest quantity of area in the least possible space. It is the best adapted to motion, both annual and diurnal, every part of the surface being nearly at the same distance from the centre of gravity and motion. Without this figure there could have been no comfortable and regular alternations of day and night in our world as we now

enjoy, and the light of the sun and the mass of waters could not have been equably distributed. Had the earth been of a cubical, prismatic, or pentagonal form, or of any other angular figure, some parts would have been comparatively near the centre of gravity, and others hundreds or thousands of miles farther from it; certain countries would have been exposed to furious tempests, which would have overturned and destroyed every object, while others would have been stifled for want of currents and agitation in the air; one part would have been overwhelmed with water, and another entirely destitute of the liquid element; one part might have enjoyed the benign influence of the sun, while another might have been within the shadow of elevations a hundred miles high, and in regions of insufferable cold. In short, while one country might have resembled a paradise, others would have been transformed into a chaos, where nothing was to be seen but barrenness and hideous desolation; but the globular figure which the Creator has given to our world prevents all such inconveniences and evils, and secures to us all the advantages we enjoy from the equable distribution of light and gravity, of the waters of our seas and rivers, and of the winds and motions of the atmosphere; and arrangements similar or analogous are enjoyed by all the other planetary worlds, in consequence of the globular figure which has been impressed upon them.

The same Divine Wisdom is displayed throughout the solar system *in the nice adjustment of the projectile velocity to the attractive power.* The natural tendency of all motion, impressed by a single force, is to make the body move in a *straight line.* The projectile force originally given to the planets, if not counteracted, would carry them away from the sun, in right lines, through the regions of infinite space. On the other hand, had the planets been acted upon solely by an attractive power proceeding from the centre, they would have moved with an increased velocity towards that centre, and, in a short time, have fallen upon the body of the sun. Now the Divine Intelligence strikingly appears in nicely proportioning and balancing these two powers, so as to make the planets describe orbits nearly circular. If these powers had not been accurately adjusted, the whole system would have run into confusion. For, were the velocity of any planet double to what would make it move in a circle or ellipse, it would

rush from its sphere through the regions of immensity, and never again return to its former orbit. Or, should half its velocity be taken away, the planet would descend obliquely towards the sun till it became four times nearer him than before, and then ascend to its former place; and by ascending and descending alternately, would describe a very eccentric orbit, and would feel the influence of the solar light and power sixteen times greater in one part of its course than in another; which would prevent such a globe as ours, and probably all the planetary bodies, from being habitable worlds. But, in this respect, every part of celestial mechanism is adjusted with the nicest skill, and the whole system appears a scene of beauty, order, and stability worthy of the intelligence of Him "who hath established the world by his wisdom, and stretched out the heavens by his understanding." And as the power of gravitation was first impressed upon matter by the hand of the Creator, so its continued action is every moment dependant on his sovereign will. Were its influence to be suspended, the whole system would immediately dissolve and run into confusion. The centrifugal force of the planets, in whirling round their axes, would shatter them into pieces and dissipate their parts throughout the circumambient spaces; every portion of matter would fly in straight lines, according as the projectile force chanced to direct at the moment this power was suspended; and the regions of infinite space, instead of presenting a prospect of beauty and order, would become a scene of derangement, overspread with the wrecks of all the globes in the universe; so that the order and stability of universal nature entirely depends upon the will and the omnipotence of the Deity in sustaining in constant action the power of universal gravitation. Were it his pleasure that the material world should be dissolved and its inhabitants destroyed, he has only to interpose his Almighty fiat, and proclaim, "Let the power of attraction be suspended," and the vast universe would soon be unhinged and return to its original chaos.

In short, the depth of the Divine Wisdom might have been illustrated from the constant proportion between the times of the periodical revolutions of all the planets, primary and secondary, and the cubes of their mean distances; from the constancy and regularity of their motions, that, amid so immense a variety of moving masses, all should observe their

due bounds and keep their appointed paths, to answer the great ends of their creation; from the exactness with which they run their destined rounds, finishing their circuits with so much accuracy as not to deviate from the periods of their revolutions a single minute in a hundred years; from the *distances* of the several planets from the sun, compared with their respective *densities;* from their velocities in their orbits compared with their distances from the central luminary, from the wonderful simplicity of the laws on which so much beauty, harmony, and enjoyment depend; and from various other considerations, all which would tend to demonstrate that He who framed the planetary system is "the only wise God," whose "understanding is infinite," and the depth of whose intelligence is "past finding out."

From what we have now stated we may see what a beautiful and divine fabric the solar system exhibits. Like all the arrangements of Infinite Wisdom, its foundations are plain and simple, but its superstructure is wonderful and diversified. The causes which produce the effects are few, but the phenomena are innumerable. While the ends to be accomplished are numerous and various, the means are the fewest that could possibly bring the design into effect. What a striking contrast is presented between the works of Omnipotence as they really exist, and the bungling schemes of the ancient astronomers? who, with all their cycles, epicycles, concentric and eccentric circles, their deferents, and solid crystalline spheres, could never account for the motions of the planetary orbs, nor explain their phenomena. The plans of the Almighty, both in the material world and in his moral government, are quite unlike the circumscribed and complex schemes of man. Like himself, they are magnificent and stupendous, and yet accomplished by means apparently weak and simple. All his works are demonstrations, not only of his existence, but of his inscrutable wisdom and superintending providence. As the accomplishments of every workman are known from the work which he executes, so the operations of the Deity evince his supreme agency and his boundless perfections. What being less than infinite could have arranged the solar system, and launched from his hand the huge masses of the planetary worlds? What mathematician could so nicely calculate their distances and arrange their motions? Or what mechanic so accurately contrive their

figures, adjust their movements, or balance their projectile force with the power of gravitation? None but He whose power is supreme and irresistible, whose agency is universal, and whose wisdom is unsearchable.

In the last place, the planetary system exhibits a display of the GOODNESS of the Creator and of his superintending care. The goodness of God is that perfection of his nature by which he delights to communicate happiness to every order of his creatures. Now all the movements and arrangements of the planetary bodies are so ordered and directed as to act in subserviency to the happiness of sentient and intelligent beings. This is evidently the grand design of all the wise contrivances to which we have adverted. The spherical figure given to all the planets for the regular distribution of the waters of the seas and rivers, and of the currents of the atmosphere; their rotation on their axes, to produce the alternate succession of day and night; the situation of the sun in the centre of the system, for the equable distribution of light and heat to surrounding planets; and an apparatus of rings and moons, to reflect a mild radiance in the absence of the sun, are contrivances which can only have a respect to the comfort and convenience of animated beings; for they can serve no purpose to mere inert matter devoid of life and intelligence, and the Creator, so far as we know, never employs *means* without a corresponding end in view. In our world the utility of these arrangements, in order to our happiness, is obvious to the least reflecting mind. Without light our globe would be little else than a gloomy prison; for it is this that cheers the heart of man, and unveils to our view the beauties and sublimities of creation; and had the earth no rotation, and were the sun continually shining on the same hemisphere, the temperate zones as well as the equatorial regions would be parched with a perpetual day, the moisture of the soil evaporated, the earth hardened, vegetables deprived of nourishment, the functions of the atmosphere deranged, and numerous other inconveniences would ensue, from which we are now protected by the existing arrangements of nature; and as such contrivances are essential to the comfort of the inhabitants of the earth, so we have every reason to conclude that these and all the additional arrangements connected with other planets are intended to promote the enjoyment of the different orders of sensitive and intelligent existence with which they are peopled.

As the object of the wise contrivances of the Deity is the communication of happiness, it would be inconsistent with every rational view we can take of his wisdom and intelligence not to admit that *the same end* is kept in view *in every part of his dominions*, however far removed from the sphere of our immediate contemplation, and though we are not permitted in the mean time to inspect the minute details connected with the economy of other worlds; for the Creator must always be considered as consistent with himself, as acting on the same eternal and immutable principles at all times, and throughout every department of his empire. He cannot be supposed to devise means in order to accomplish important ends in relation to our world, while in other regions of creation he devises means *for no end at all.* To suppose, for a moment, such a thing possible, would be highly derogatory to the Divine character, and would confound all our ideas of the harmony and consistency of the attributes of him who is "the only wise God." We have, therefore, the highest reason to conclude, that not only this earth, but the whole of the planetary system, is a scene of *divine benevolence;* for it displays to our view a number of magnificent globes, with special contrivances and arrangements, all fitted to be the abodes of intelligent beings, and to contribute to their enjoyment. Every provision has been made to supply them with that *light* which unfolds the beauties of nature and the glories of the firmament. All the arrangements for its equable distribution have been effected, and several wonderful modes unknown in our world have been contrived for alleviating their darkness in the absence of the sun, all which contrivances are, doubtless, accompanied with many others which lie beyond the range of our conception, and which our remote distance prevents us from contemplating. In proportion, then, as the other planets exceed the earth in size, in a similar proportion, we may conceive, is the extent of that theatre on which the Divine goodness is displayed. If this "earth is full of the goodness of the Lord," if the benevolence of the Creator has distributed unnumbered comforts among every order of creatures here below, what must be the exuberance of his bounty, and the overflowing streams of felicity enjoyed in worlds which contain thousands of times the population of our globe! If a world which has been partly deranged by the sin of its inhabitants abounds with so many pleasures, what numerous

sources of happiness must abound, and what ecstatic joys must be felt in those worlds where moral evil has never entered, where diseases and death are unknown, and where the inhabitants bask perpetually in the regions of immortality. Were we permitted to take a nearer view of the enjoyments of some of those worlds, were we to behold the magnificent scenery with which they are encircled, the riches of Divine munificence which appear on every hand, the inhabitants adorned with the beauties of moral perfection, and every society cemented by the bond of universal love, and displaying the virtues of angelic natures, it is highly probable that all the enjoyments of this terrestrial sphere would appear only "as the drop of a bucket and the small dust of the balance," and as unworthy of our regard in comparison of the overflowing fountains of bliss which enrich the regions and gladden the society of the celestial worlds. In this point of view what a glorious and *amiable* being does the eternal Jehovah appear! "God is love." This is his name and his memorial in all generations and throughout all worlds. Supremely happy in himself and independent of all his creatures, his grand design in forming and arranging so many worlds could only be to display the riches of his beneficence, and to impart felicity, in all its diversified forms, to countless orders of intelligent beings and to every rank of perceptive existence. And how *extensive* his goodness is, not only throughout the planetary system, but over all the regions of universal nature, it is impossible for the tongues of men or angels to declare, or the highest powers of intelligence to conceive. But of this we are certain, that "Jehovah is good to all;" that "his bounty is great above the heavens;" and that "his tender mercies are over all his works."

CHAPTER VI.

SUMMARY VIEW OF THE MAGNITUDE OF THE PLANETARY SYSTEM.

Having, in the preceding pages, given a brief description of the principal facts and phenomena connected with the solar system, and offered a few reflections suggested by the sub-

ject, it may not be inexpedient to place before the reader a summary view of the magnitude of the bodies belonging to this system, as compared with the population and magnitude of the globe on which we live. In this summary statement I shall chiefly attend to the *area* or superficial contents of the different planets, which is the only accurate view we can take of their magnitudes, when we compare them with each other as habitable worlds. The population of the different globes is estimated, as in the preceding descriptions, at the rate of 280 inhabitants to a square mile, which is the rate of population in England, and yet this country is by no means overstocked with inhabitants, but could contain, perhaps, double its present population.

	Square Miles.	Population.	Solid Contents.
Mercury	32,000,000	8,960,000,000	17,157,324,800
Venus	191,134,944	53,500,000,000	248,475,427,200
Mars	55,417,824	15,500,000,000	38,792,000,000
Vesta	229,000	64,000,000	10,035,000
Juno	6,380,000	1,786,000,000	1,515,250,000
Ceres............	8,285.580	2,319,962,400	2,242,630,320
Pallas	14,000,000	4,000,000,000	4 900,000,000
Jupiter	24,884,000,000	6,967,520,000,000	368,283,200,000,000
Saturn	19,600,000,000	5,488,000,000,000	261,326,800,000,000
Saturn's outer ring	9,058,803,600		
Inner ring	19,791,561,636	8,141,963,826,080	1,442,518,261,800
Edges of the rings	228,077,000		
Uranus	3,848,460,000	1,077,568,800,000	22,437,804.620,000
The Moon	15,000,000	4,200,000,000	5,455,000,000
Jupiter's satellites	95,000,000	26,673,000,000	45,693,970,126
Saturn's satellites.	197,920,800	55,417,824,000	98,960,400,000
Uranus's satellites	169,646,400	47,500,992,000	84,823,200,000
Amount......	78,195,916,784	21,894,974,404,480	654,038,348,119,246

From the above statement, the real magnitude of all the moving bodies connected with the solar system may at once be perceived. If we wish to ascertain what proportion these magnitudes bear to the amplitude of our own globe, we have only to divide the different amounts stated at the bottom of the table by the area, solidity, or population of the earth. The amount of area, or the superficial contents of all the planets, primary and secondary, is 78,195,916,784; or above *seventy-eight thousand millions* of square miles. If this sum be divided by 197,000,000, the number of square miles on the surface of our globe, the quotient will be 397; showing that the

surfaces of these globes are 397 times more expansive than the whole surface of the terraqueous globe ; or, in other words, that they contain an amplitude of space for animated beings equal to nearly *four hundred worlds* such as ours. If we divide the same amount by 49,000,000, the number of square miles in the habitable parts of the earth, the quotient will be 1595; showing that the surface of all the planets contains a space equal to one thousand five hundred and ninety-five times the area of all the continents and islands of our globe. If the amount of population which the planets might contain, namely, 21,894,974,404,480, or nearly *twenty-two billions*, be divided by 800,000,000, the population of the earth, the quotient will be 27,368; which shows that the planetary globes could contain a population more than twenty-seven thousand times the population of our globe ; in other words, if peopled in the proportion of England, they are equivalent to twenty-seven thousand worlds such as ours in its present state of population. The amount of the third column expresses the number of solid miles comprised in all the planets, which is 654,038,348,119,246, or more than *six hundred and fifty-four billions*. If this number be divided by 263,000,000,000, the number of cubical miles in the earth, the quotient will be 2483 ; which shows that the solid bulk of the other planets is two thousand four hundred and eighty-three times the bulk of our globe. Such is the immense magnitude of our planetary system, without taking into account either the sun or the hundreds of comets which have been observed to traverse the planetary regions.

Great, however, as these magnitudes are, they are far surpassed by that stupendous globe which occupies the centre of the system. The surface of the sun contains 2,432,800,000,000 square miles (nearly two and a half billions). If this sum be divided by 197 billions, the number of square miles on the earth's surface, the quotient will be 12,350, which shows that the surface of the sun contains *twelve thousand three hundred aud fifty* times the quantity of surface on our globe. If the same sum be divided by 78,195,916,784, the number of square miles in all the planets, the quotient will be 31, showing that the area of the surface of the sun is *thirty-one* times greater than the area of all the primary planets, with their rings and satellites. The solid contents of the sun amount to 356,818,739,200,000,000, or nearly three hundred

and fifty-seven billions of cubical miles, which number, if divided by 654,038,348,119,246, the number of solid miles in all the planets, will produce a quotient of 545, which shows that the sun is five hundred and forty-five times larger than all the planetary bodies taken together. Such is the vast and incomprehensible magnitude of this stupendous luminary, whose effulgence sheds day over a retinue of revolving worlds, and whose attractive energy controls their motions and preserves them all in one harmonious system. If this immense globe be flying through the regions of space at the rate of sixty thousand miles an hour, as is supposed, and carrying along with it all the planets of the system, it presents to the mind one of the most sublime and overwhelming ideas of motion, magnitude, and grandeur which the scenes of the universe can convey.

The comparative magnitudes of the different bodies in the system are represented to the eye in Fig. XCI., where the circle at the top, No. 1, represents Jupiter; No. 2, Saturn; No. 3, Uranus; No. 4, the Earth; adjacent to which, on the left, is the Moon; No. 5, Mars; No. 6, Venus; and No. 7, Mercury. The four small circles at the bottom are the planets Vesta, Juno, Ceres, and Pallas, whose proportional sizes cannot be accurately represented. The other small circles connected with Jupiter, Saturn, and Uranus, are intended to represent the satellites of these planets, which in general may be estimated as considerably larger than our moon. These comparative magnitudes are only approximations to the truth; for it would require a large sheet were we to attempt delineating them with accuracy; but the figure will convey to the eye a *general* idea of the comparative bulks of these bodies, in so far as it can be conveyed by a comparison of their diameters;* but no representation on a plane surface can convey an idea of the *solid contents* of these globes as compared with each other. The reader will perceive the great disparity of globes, whose diameters do not differ very widely from each other, if he place a globe of twelve inches diameter beside one of eighteen inches diameter. Though these globes differ only six inches in their diameters, yet he will at once perceive that the eighteen-inch globe contains more than double

* The reader will find a comparative view of the distances and magnitudes of the planets, engraved on a very large sheet, in "Burritt's Geography of the Heavens," published at Hartford, North America.

Fig. XCII.

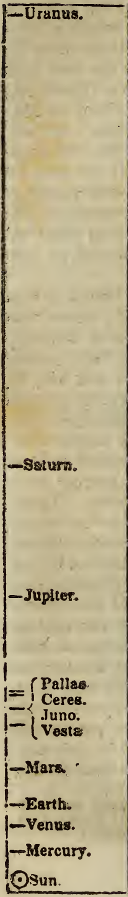
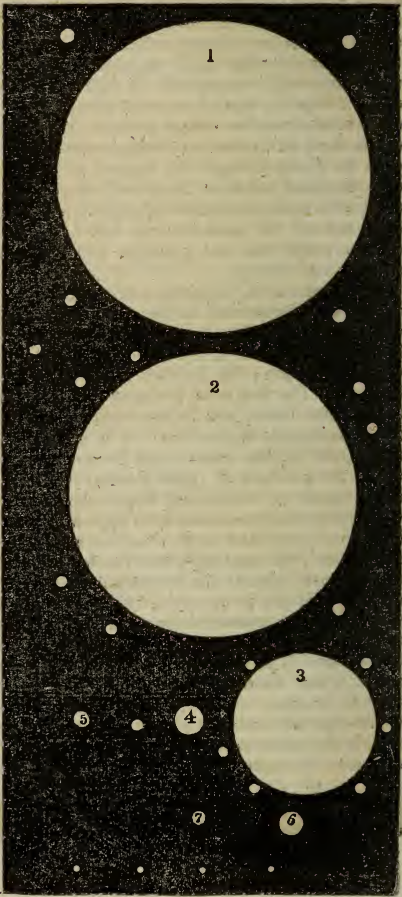


Fig. XCI.



the surface of the twelve-inch ; and the *solid* space which it occupies contains 3 3-8 times the space occupied by the smaller globe. Were the sun to be represented in its proportional size to Jupiter and the other planets, it would fill a space *twenty inches in diameter*. On the same scale in which the planets are delineated, Saturn's ring would occupy a space four and a half inches in diameter. From these representations we may see how small a space our earth occupies in the planetary system, and what an inconsiderable appearance it presents in comparison with Jupiter, Saturn, and Uranus. Fig. XCII. represents the *proportional distances* of the primary planets from the sun, from which it will be seen that Saturn, which was formerly considered the most distant planet, occupies nearly the middle of the system.

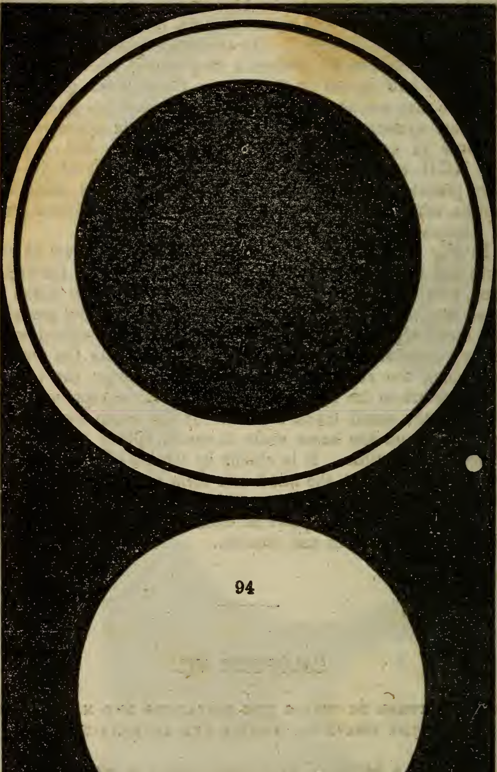
In Fig. XCIII. is represented a comparative view of the earth and the rings of Saturn. The small circle at the right-hand side represents the lineal proportion of our globe to those stupendous arches, so that the eye may easily perceive that hundreds of worlds such as ours could be enclosed within such expansive rings. Fig. XCIV. represents the proportion which the sun bears to the planet Jupiter, the largest planetary orb in the system. The large circle represents the sun, and the small circle Jupiter. If the earth were to be represented on the same scale, it would appear like a point scarcely perceptible. It is chiefly by the aid of such tangible representations that the mind can form any idea approximating to the reality of such magnitudes and proportions ; and, after all its efforts, its views of such stupendous objects are exceedingly imperfect and obscure.

CHAPTER VII.

ON THE METHOD BY WHICH THE DISTANCES AND MAGNITUDES OF THE HEAVENLY BODIES ARE ASCERTAINED.

THERE is a degree of skepticism among a certain class of readers in regard to the conclusions which astronomers have deduced respecting the distances and magnitudes of the ce-

Fig. XCIII.



lestial bodies. They are apt to suspect that the results they have deduced are *merely conjectural*, and that it is impossible for human beings to arrive at anything like certainty, or even probability, in regard to distances so immensely great, and to magnitudes so far surpassing everything we see around us on this globe. Hence it is that the assertions of astronomers as to these points are apt to be called in question, or to be received with a certain degree of doubt and hesitation, as if they were beyond the limits of truth or probability. And hence such persons are anxious to inquire, "How can astronomers find out such things?" "Tell us by what methods they can measure the distances of the planets and determine their bulks?" Such questions, however, are more easily proposed than answered; not from any difficulty in stating the principles on which astronomers proceed in their investigations, but from the impossibility, in many instances, of conveying an idea of these principles to those who are ignorant of the elements of geometry and trigonometry. A very slight acquaintance with these branches of the mathematics, however, is sufficient to enable a person to understand the mode by which the distances of the heavenly bodies are determined; but a certain degree of information on such subjects is indispensably requisite, without which no satisfactory explanation can be communicated.

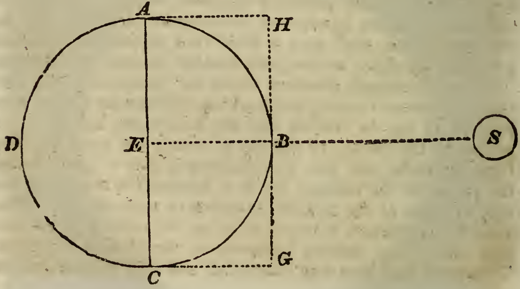
In offering a few remarks on this subject, I shall, in the first place, state certain considerations, level to the comprehension of the general reader, which prove that the celestial bodies are much more distant from the earth, and, consequently, much larger than they are generally supposed to be by the vulgar, and those who are ignorant of astronomical science; and, in the next place, shall give a brief view of the mathematical principles on which astronomers proceed in their calculations.

When a common observer views the heavens for the first time, previous to having received any information on the subject, he is apt to imagine that the sun, moon, and stars are placed in the canopy of the sky at nearly the same distance from the earth, and that this distance is only a little beyond the region of the clouds; for it is impossible, merely by the eye, to judge of the relative distances of such objects. Previous to experience, it is probable that we could form no correct idea of the relative distances of any objects whatever. The young man who was born blind, and who was restored to

sight at the age of thirteen, by an operation performed by Mr. Cheselden, could form no idea of the distances of the new objects presented to his visual organs. He supposed everything he saw touched his eyes, in the same manner as everything he felt touched his skin. An object of an inch diameter placed before his eyes, which concealed a house from his sight, appeared to him as large as the house. What he had judged to be round by the help of his hands he could not distinguish from what he had judged to be square; nor could he discern by his eyes whether what his hands had perceived to be above or below was really above or below; and it was not till after two months that he could distinguish pictures from solid bodies. In like manner we are apt to be deceived in our estimate of the distances of objects by the eye, particularly of those which appear in the concave of the heavens; and reason and reflection must supply the deficiency of our visual organs before we can arrive at any definite conclusions respecting objects so far beyond our reach.

That the heavenly bodies, particularly the sun, are much greater than they appear to the vulgar eye, may be proved by the following consideration: When the sun rises due east in the morning, his orb appears just as large as it does when he comes to the meridian at midday. Yet it can be shown that the sun, when he is on our meridian, is about 4000 miles nearer us than when he rose in the morning. This may be illustrated by the following figure.

Fig. XCV.

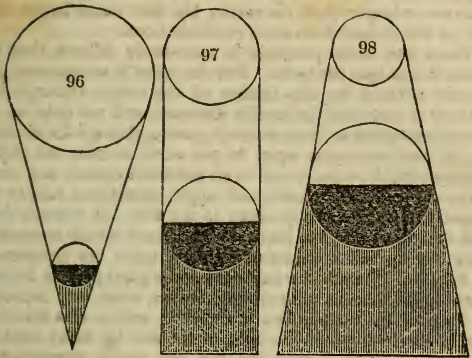


Let A B C D represent the earth, and S the sun at the point of his rising. Suppose the line A E C to represent the meridian of a certain place, and A or E the place of a spectator. When the sun, in his apparent diurnal motion, comes opposite the meridian A C, he is a whole semidiameter of the earth nearer the spectator at E than when he appeared in the eastern horizon. This semidiameter is represented by the lines A H, E B, C G, and is equal to 3965 miles. Now were the sun only four thousand miles distant from the earth, and, consequently, eight thousand miles from us at his rising, he would be nearly four thousand miles nearer us when on the meridian than at his rising; and, consequently, he would appear twice the diameter, and four times as large in surface as he does at the time of his rising. But observation proves that there is no perceptible difference in his apparent magnitude in these different positions; therefore the sun must be much more distant from the earth than four thousand miles. If his distance were only 120,000 miles, his apparent diameter would appear 1-30 part broader when on the meridian than at the time of his rising, and the difference could easily be determined; but no such difference is perceptible; therefore the sun is still more distant than one hundred and twenty thousand miles. And, as the *real* size of any body is in proportion to its distance, compared with its *apparent* size, the sun must, from this consideration alone, be *more* than 1200 miles in diameter, and must contain *more* than nine hundred millions of cubical miles. But how much greater his distance and magnitude are than what is now stated cannot be determined from such observations.

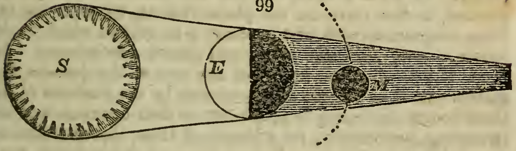
The same idea may be illustrated as follows: Suppose a spectator at Edinburgh, which may be represented by the point A (Fig. XCV.), and another at Capetown, in the southern extremity of Africa, about the time of our winter solstice, which position may be represented by the point E; both spectators might see the sun at the same moment, and he would appear exactly of the same size from both positions. Yet such spectators would be more than 4000 miles distant from each other in a *straight line*, and the observer at Capetown would be several thousands of miles nearer the sun than the one at Edinburgh. Now if the sun were only a few thousands of miles from the earth, he would appear of a very different magnitude to observers removed so far from each

other, which is contrary to fact. Consequently, the sun must be at a very great distance from the earth, and his real size proportionable to that distance. For experience proves that objects which are of great magnitude may appear comparatively small when removed from us to a great distance. The lofty vessel, as it recedes from the coast towards the ocean, gradually diminishes in its apparent size, till at length it appears as a scarcely distinguishable speck on the verge of the horizon; and the aeronaut with his balloon, when they have ascended beyond the region of the clouds, appear only as a small dusky spot on the canopy of the sky, and sometimes entirely disappear.

The following argument, which is level to the comprehension of every reflecting mind, proves that the sun is larger than the whole globe of the earth, and that the moon is considerably less. Previous to the application of the argument to which I allude, it may be proper to illustrate the law of *shadows*. The law by which the shadows of globes are projected is as follows: When the luminous body is larger in diameter than the opaque body, the shadow which it projects converges to a point which is the vertex of a cone, as in Fig. XCVI. When the luminous and the opaque body are of an equal size, the shadow is cylindrical, and passes on from the opaque body to an indefinite extent, as represented in Fig. XCVII. When the luminous body is less than the opaque, the shadow extends in breadth beyond the opaque body, and grows broader and broader in proportion to its distance from the opaque globe, as in Fig. XCVIII. This may be illustrated by holding a ball three or four inches in diameter opposite to a candle, when the shadow of the ball will be seen to be larger in diameter in proportion to the distance of the wall or screen on which the shadow is projected. Now it is well known, and will readily be admitted, that an eclipse of the moon is caused by the shadow of the earth falling upon the moon, when the sun, earth, and moon are nearly in a straight line with respect to each other; and that an eclipse of the sun is caused by the shadow of the moon falling upon a certain portion of the earth. Let *S* (Fig. XCIX.) represent the sun; *E* the earth; and *M* the moon, nearly in a straight line, which is the position of these three bodies in an eclipse of the moon The shadow of the earth, at the distance of the moon, is found to be of a less diameter than the



99



diameter of the earth. This is ascertained by the time which the moon takes in passing through the shadow. The real breadth of that shadow, at the moon's distance from the earth, is about 5900 miles, sometimes more and sometimes less, according as the moon is nearer to or farther from the earth; but the diameter of the earth is nearly 8000 miles; therefore the shadow of the earth gradually decreases in breadth in its progress through space, and, by calculation, it is found that it terminates in a point, as in Fig. XCVI., at the distance of about 850,000 miles. But when a luminous globe causes the shadow of an opaque globe to converge towards a point, as in Fig. XCVI., the luminous body must be larger in diameter than the opaque one. The sun is the luminous body which causes the earth to project a shadow on the moon; this shadow, at the moon, is less in breadth than

the diameter of the earth; therefore it inevitably follows *that the sun is larger than the earth;* but how much larger can not be determined from such considerations.

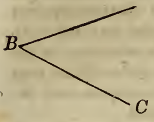
From the same premises it necessarily follows that the moon is *less* than the earth. For the moon is sometimes completely covered by the shadow of the earth, although this shadow is less than the earth's diameter, and not only so, but sometimes takes an hour or two in passing through the shadow. If the sun were only equal to the earth in size, the earth's shadow would be projected to an indefinite extent, and be always of the same breadth, and might sometimes eclipse the planet Mars when in opposition to the sun. If the sun were less than the earth, the shadow of the earth would increase in bulk the farther it extended through space (as represented in Fig. XCVIII.), and would eclipse the great planets Jupiter, Saturn, and Uranus, with all their moons, when they happened to be near their opposition to the sun; and in this case they would be deprived of the light of the sun for many days together. In such a case, too, the sun would sometimes be eclipsed to the earth by the planet Venus, when in its inferior conjunction with that luminary; an eclipse which might cause a total darkness of several hours continuance. In short, if the sun were less than any one of the planets, the system would be thrown into confusion by the shadows of all these bodies increasing in proportion to their distance, and interrupting, periodically, for a length of time, the communications of light and heat. But as none of these things ever happen, it is evident that the sun is much larger than the whole terraqueous globe.

All that requires to be taken for granted by the unlearned reader in this argument is, that the earth is a globular body; that an eclipse of the moon is caused by the shadow of the earth falling upon that orb; and that the shadow of the earth, at the distance of the moon, is of less breadth than the earth's diameter. The first two positions will readily be admitted; and the third position, respecting the breadth of the earth's shadow, may be received on the ground of what has been above stated, and on the authority of astronomers. For, if they were ignorant of this circumstance, they could not calculate eclipses with so much accuracy as they do, and predict the precise moment of the beginning and end of a lunar eclipse. If, then, any individual is convinced, from the con-

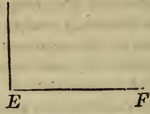
sideration above stated, that the sun must be much larger than the earth, he has advanced one step in his conceptions of the magnificence of the heavenly bodies, and may rest with confidence on the assertions of astronomers in reference to the *real* distances and magnitudes of these orbs, although he may not be acquainted with the mathematical principles and investigations on which their calculations proceed.

Before proceeding to the illustration of the trigonometrical principles on which astronomers proceed in determining the true distances of the heavenly bodies, it may be requisite, for the unlearned reader, to give a description of the nature of angles and the mode by which they are measured. An angle is the opening between any two lines which touch each other in a point; and the width of the opening determines the extent of the angle, or the number of degrees or minutes it contains. Thus, if we open a pair of compasses, the legs of which may be represented by *A B*, *B C*, Fig. C., an angle is formed of different dimensions, according as the extremities of the legs are removed farther from or brought nearer to each other. If the legs are made to stand perpendicular to each other, as in Fig. CI., the angle is said to be a *right angle*, and contains ninety degrees, or the fourth part of a circle. The walls of a room generally stand at right angles to the floor. If the legs be separated more than a right angle, they form what is termed an *obtuse angle*, as in Fig. CII. When the angle is less than a right angle, it is called an *acute angle*, as in Fig. C., and, consequently, contains a less number of degrees than ninety. All angles are measured by the arc of a circle described on the angular point; and every circle, whether great or small, is divided into 360 equal parts, called degrees. Thus, if I want to know the quantity of an angle at *K* (Fig. CIII.), I place one point of the compasses at the angular point *K*, and describe the arc of a circle between the two sides *L K*, *K M*, and whatever number of degrees of a circle is contained between them is the quantity or measure of the angle. If, as in the present case, the angle contains the eighth part of a circle or half a right angle, it is said to be an angle of forty-five degrees. A *triangle* is a figure which contains three angles and three sides, as *O P Q*, Fig. CIV. It is demonstrated by mathematicians, that the three angles of every triangle, whatever proportion these angles may bear to each other, are exactly equal to two right angles,

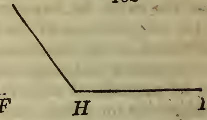
100



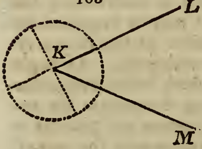
101



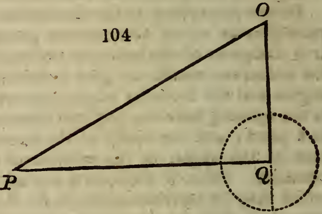
102



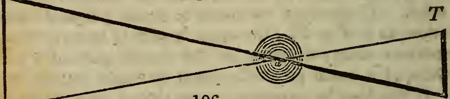
103



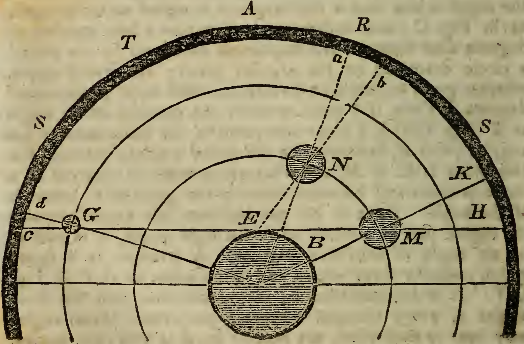
104



105



106



or 180 degrees. Thus, in the triangle $O\ P\ Q$, the angle at Q is a right angle, or ninety degrees, and the other two angles, O and P, are together equal to ninety degrees; so that, if one of these angles be known, the other is found by subtracting the number of degrees in the known angle from ninety. Thus, if the angle at P be equal to thirty degrees, the angle at O will be equal to sixty degrees. Hence, if any two angles of a triangle be known, the third may be found by subtracting the sum of the two known angles from 180 degrees, the remainder will be the number of degrees in the third angle. All the triangles have their greatest sides opposite to their greatest angles; and if all the *angles* of the triangle be equal, the *sides* will also be equal to each other.

If any three of the six parts of a triangle be known (excepting the three angles), *all the other parts may be known from them.* Thus, if the side $P\ Q$, and the angles at P and Q be known, we can find the length of the sides $P\ O$ and $O\ Q$. It is on this general principle that the distances and magnitudes of the heavenly bodies are determined.

In order to understand and apply this principle, it is necessary that we explain the nature of a *parallax*. A parallax denotes the change of the apparent place of any heavenly body, caused by being seen from different points of view. This may be illustrated by terrestrial objects as follows: Suppose a tree 40 or 50 yards distant from two spectators, who are 15 or 20 yards distant from each other; the one will perceive the tree in a line with certain objects near the horizon, which are considerably distant from those which appear in the direction of the tree, as viewed from the station occupied by the other spectator. The difference between the two points near the horizon where the tree appears to coincide to the two different spectators is the *parallax* of the object. If the tree were only 20 or 25 yards distant, the parallax would be twice as large; or, in other words, the points in the horizon where it was seen by the two spectators would be double the distance, as in the former case; and if the tree were two or three hundred yards distant, the parallax would be proportionably small. Or, suppose two persons sitting near each other at one side of a room, and a candle placed on a table in the middle of the room, the points on the opposite wall where the candle would appear to each of the two persons would be considerably distant from each other; and this dis-

tance may be called the parallax of the candle as viewed by the two observers. This may be illustrated by Fig. CV., where *R* and *S* may represent the positions of the observers; *a* the candle or tree; and *T* and *U* the points on the opposite wall or in the horizon where the candle or the tree appears to the respective observers. The observer at *R* sees the intermediate object at *U;* and the one at *S* sees it in the direction *S T.* The angle *R a S*, which is equal to the angle *T a U*, is called the angle of parallax, which is the difference of position in which the object is seen by the two observers. If, then, the distance between the observers *R S* be known, and the quantity of the angle *R a S*, the distance between the observers and the object can also be known by calculation.

Let us now apply this principle to the heavenly bodies. In Fig. CVI. let the semicircle *S*, *T*, *A*, *R*, *S* represent a section of the concave of the heavens; the middle circle, *E C*, the earth; *M* the moon; *C* the centre of the earth; and *E H* the sensible horizon of a spectator at *E*. It is evident that if the moon be viewed from the earth at the point *E*, she will be seen in the horizon at the point *H;* but were she viewed at the same time from *C*, the centre of the earth, she would appear among the stars at the point *K*, in a more elevated position than when seen from the surface of the earth at *E*. The difference between those two apparent positions of the moon, or the angle *K M H*, is called the moon's *horizontal parallax.* Astronomers know from calculation in what point of the heavens the moon would appear as viewed from the earth's centre; and they know from actual observation where she appears as viewed from the surface; and, therefore, can find the difference of the two positions, or the angle of parallax. This angle might likewise be found by supposing two spectators on different parts of the earth's surface viewing the moon at the same time. Suppose a spectator at *E*, who sees the moon in the horizon at *H;* and another observer, on the same meridian, at *B*, who sees her in his zenith at *K;* the parallax, as formerly, will be *K H*.

The parallax of a heavenly body decreases in proportion to its altitude above the horizon, and at the zenith (*A*) it is nothing, for the line from the centre of the earth coincides with that from the surface, as *C E A*. Thus, the parallax of the moon at *N* (*a b*) is less than the horizontal parallax, *K H;* but from the parallax observed at any altitude, the horizontal parallax

can be deduced; and it is from this parallax that the distance of the moon or any other heavenly body is determined. *The greater the distance of any body from the earth, the less is its parallax.* Thus the heavenly body G, which is farther from the earth than the moon, has a less parallax ($c\ d$) than that of the moon, $K\ H$.

Now the parallax of the moon being known, it is easy to find the distance of that orb from the earth; for in every triangle, if one side and two angles be known, the other angle and the other two sides can also be found. In the present case, we have a triangle $E\ M\ C$, in which the side $E\ C$, or the semidiameter of the earth, is known. The angle $M\ E\ C$ is a right angle, or ninety degrees; and the parallactic angle $E\ M\ C$ is supposed to be found by observation. From these *data*, by an easy trigonometrical calculation, the length of the side $C\ M$, or the distance of the moon from the centre of the earth, can be determined with the utmost precision, provided the angle of parallax has been accurately ascertained.

Before proceeding to illustrate by examples the method of calculating the distances of the heavenly bodies when the parallax is found, I shall present an example or two of the mode of computing the heights and distances of terrestrial objects, the principle on which we proceed being the same in both cases. Suppose it were required to find the height of the tower $C\ B$ (Fig. CVII.), we first measure the distance from the bottom of the tower, B, to a station at the point A, which suppose to be one hundred feet. From this station, by a quadrant or other angular instrument, we take the angle of elevation of the top of the tower, or the angle $C\ A\ B$, which suppose to be forty-seven and a half degrees. Here we have a triangle in which we have one side, $A\ B$, and two angles; namely, the angle at $A = 47\frac{1}{2}°$, and the angle at B, which is a right angle, or $90°$, as the tower is supposed to stand perpendicular to the ground; therefore the side $C\ B$, which is the height of the tower, can be found, and likewise the other side, $A\ C$, if required. To find $C\ B$, the height of the tower, we make $A\ B$ the radius of the circle, a portion of which measures the angle A; and the side $B\ C$, or the height of the tower, becomes the tangent of that angle. And as there is a certain known proportion between the radius of every circle and the tangent, the height of the tower will be found by the following proportion: As the radius: is to the tangent of the

angle *A*, 47½° : : so is the side *A B*, 100 feet: to *C B*, the height of the tower= 109 1-8 feet. The following is the calculation by logarithms:

Logarithm of the 2d term—Tangent of 47 1-2°...........	10·0379475
Logarithm of *A B*=100 feet—3d term....................	2·0000000
	12·0379475
Logarithm of radius—1st term..............................	10·0000000
Logarithm of *C B*, 4th term=109 1-8 feet=..............	2·0379475

By this calculation the height of the tower is found with the greatest nicety, provided the measurement of the side *A B*, and the angle *A*, have been taken with accuracy.

Again: Suppose it were required to measure the distance between a tree *E*, and a house *D*, on the opposite side of a river. We first measure a space from *E* to *F* (Fig. CVIII.), suppose 200 yards, in a right line, and then find the angles *E* and *F* at each end of this line. Suppose the angle at *E* to be seventy-three degrees and the angle at *F* sixty-eight degrees. As all the angles of a triangle are equal to two right angles, or 180°, if we add these two angles and subtract their sum from 180°, the remainder, 39°, will be the measure of the angle at *D*. It is a demonstrated proposition in trigonometry, that *in any plane triangle, the sides are in the same proportion as the sines of the opposite angles.* A *sine* is a line drawn through one extremity of an arc perpendicular upon the diameter or radius passing through the other extremity, as *a d* (Fig. CVII.) In order, then, to find the distance (*E D*) between the tree and the house on the other side of the river, we state the following proportion: As the sine of *D*, 38°, the angle opposite to *E F*, the known side: is to the sine of the angle *F*, 68°, opposite the side sought, *E D*: : so is the length of the line *E F*=200 yards: to the distance, *E D*, between the tree and the house =294 2-3 yards. The following is the operation by logarithms:

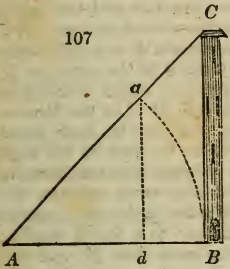
2d term—Sine of angle, *F*=68°..........................	9·9671659
3d term—*E F*=200 yards. Log............................	2·3010300
	12·2681959
1st term—Sine of angle, *D*=39°..........................	9·7988718
4th term—*D E*=294 2-3 yards=............................	2·4693241

In these examples the logarithms of the second and third

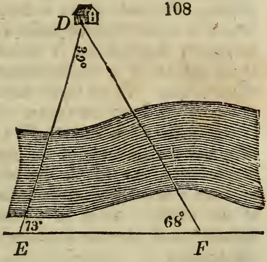
terms of the proportion are added, and from their sum the logarithm of the first term is subtracted, which leaves the logarithm of the fourth term ; as in common numbers, the second and third terms are multiplied together, and their product divided by the first term ; addition of logarithms corresponding to multiplication of whole numbers, and subtraction to division. The logarithms of common numbers, and of sines and tangents, are found in tables prepared for the purposes of calculation.

I shall now state an example or two in reference to the ce-

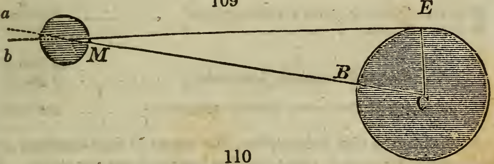
107



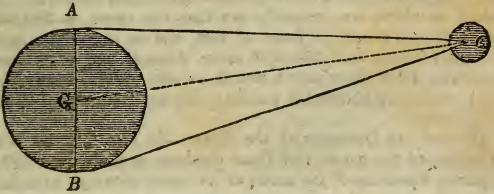
108



109



110



lestial bodies. Suppose it is required to find the distance of the moon from the earth. In Fig. CIX., let *E C* represent the earth; *M* the moon; *E* the place of a spectator observing the moon in his sensible horizon: *E M b* and *C M a* the direction of the moon as seen from the centre of the earth at *C*, or from its surface at *B*; *a* the place of the moon as seen from the centre, and *b* its place as seen from its surface at *E*; or, in other words, the moon's *horizontal parallax.* This parallax, at the moon's mean distance from the earth, is found to be 57 minutes, 5 seconds. Here, then, we have a triangle, *C E M*, of which we have one side and two angles given. The side given is the semidiameter of the earth, *E C*, which is equal to 3965 miles; the angle at *E* is a right angle, or ninety degrees, for it forms a tangent to the circle at *E*; the angle at *M* is the horizontal parallax, which is found by observation. From these data, the side *M C*, or the distance of the moon from the centre of the earth, may be easily found. If we make *C M* radius, *E C* will be the sine of the angle *M*; and the distance of the moon is found from the following proportion: As *E C*, the sine of fifty-seven minutes, five seconds: is to 3965, the number of miles in the semidiameter of the earth: : so is *M C*, the radius: to a fourth number, 238,800 = *M C* = the distance of the moon from the centre of the earth.

2d term—3965=the earth's semidiameter	3·598243
3d term—Radius	10·000000
	13 598243
1st term—Sine of 57 minutes, 5 seconds	8·220215
M C, distance of the moon, 238,800 miles=	5·378028

According to this calculation, the moon is two hundred and thirty-eight thousand, eight hundred miles from the earth. In round numbers we generally say that the moon is 240,000 miles distant; and, in point of fact, she is sometimes considerably more than 240,000 miles distant, and sometimes less than the number above stated, as she moves in an elliptical orbit, her horizontal parallax varying from 54 to above 60 minutes.

To find the Diameter of the Moon.—In Fig. CX. let *A G B* represent the moon, and *C* an observer at the earth. The apparent diameter of the moon at its mean distance, as meas-

ured by a micrometer, is 31 minutes, 26 seconds, represented by the angle $A\ C\ B$; the half of this, or the angle formed by the semidiameter of the moon, $A\ C\ G$, is 15 minutes, 43 seconds. The distance of the moon, $G\ C$, is supposed to be found as above stated, namely, 238,800 miles. Here, then, we have the angle $C\ A\ G$, which is a right angle, and the angle $A\ C\ G = 15'\ 43''$, which is found by observation; and the side $C\ G$, or the distance of the moon from the earth. We can therefore find the side $A\ G$, or the semidiameter of the moon, by the following proportion: As radius : is to $C\ G$, the distance of the moon, 238,800 miles : : so is the sine of $A\ C\ G$, $15'\ 43''$: to the number of miles contained in the moon's semidiameter, $A\ G = 1091$ 1-2, which, being doubled gives 2183 miles as the diameter of the moon.

2d term—$C\ G$=238,800—Log.	5·378028
3d term—Sine of $A\ C\ G$, 15′ 43″	7·660059
	13·038087
1st term—Radius	10·000000
Semidiameter of the moon, 1,091 1-2=	3·038087
2	
Diameter of the moon=... 2,183	

Such is the general mode by which the distances and magnitudes of the heavenly bodies are calculated. I am aware that the general reader, who is unacquainted with the principles of trigonometry, may find a little difficulty in comprehending the statements and calculations given above; but my design simply was to convey an idea of the *principle* on which astronomers proceed in their computations of the distances and bulks of the celestial orbs, and to excite those who are anxious to understand the subject, to engage in the study of plane trigonometry, a study which presents no great difficulty to any one who is already a proficient in common arithmetic. I conclude the subject with the following

General Remarks.—1. Before the bulks of the heavenly bodies can be determined, their *distances* from the earth must first be ascertained. When their distances are found, it is quite an easy matter to determine their *real* bulks from their *apparent* magnitudes. 2. *The semidiameter of the earth forms the groundwork of all our calculations respecting the distances of the celestial orbs.* Were we ignorant of the di-

mensions of the earth, we could not find the real distance and magnitude of any heavenly body; and it is owing to the comparatively small diameter of the earth that it becomes difficult in some cases to determine with accuracy the parallaxes of certain heavenly bodies. Were we placed on a planet such as Jupiter, whose diameter is more than eleven times that of our globe, it would be much more easy to find the parallaxes of the sun and planets. The parallaxes of Jupiter's moons, as observed from that planet, will form pretty large angles and be easily perceptible; and so likewise will be the parallaxes of the sun and the other planets which are visible from that globe. 3. *The chief difficulty* in finding the distances of the heavenly bodies *is to determine accurately the precise quantity of their parallaxes.* In the case of the moon there is no difficulty, as her horizontal parallax amounts to nearly one degree, and can be taken with the greatest nicety; but the sun's parallax is so small that it was some time before it was accurately determined. It was for this purpose, among others, that Captain Cook's first expedition to the Pacific Ocean was undertaken, in order that the astronomers connected with it might observe the transit of Venus at the island of Tahiti; since which time the sun's distance has been ascertained within the one eighty-seventh part of his true distance, which likewise determines very nearly the true proportional distance and magnitudes of all the planets. This circumstance accounts for the fact, that in books of astronomy published about a century ago, the distances and magnitudes of the sun and planets are estimated somewhat lower than they are now found to be, the improvements which have been made in the construction of astronomical instruments having enabled modern observers to measure parallactic angles with greater niceness and accuracy. 4. When the parallax of any heavenly body is once accurately found, and its apparent diameter measured, its real distance and bulk can be as certainly known as the price of any quantity of merchandise which is calculated by the rule of proportion. 5. From what has been stated above, we may learn the importance of knowing all the properties of a triangle, and the art of measuring angles. At first sight it may appear to be a matter of trivial importance to know that the radius of a circle bears a certain known proportion to the sine or tangent of a certain angle; that the *sides* of any triangle are in the same proportion as the *sines* of the opposite angles; and

that the three angles of every plane triangle are exactly equal to two right angles. Yet such truths form the foundation of all the discoveries which have been made respecting the magnitudes and distances of the great bodies of the universe, and of the ample conceptions we are now enabled to form of the vast extent of creation, and of the attributes of its adorable Creator.

Those persons who feel themselves unable to comprehend clearly the principles and calculations above stated, may rest satisfied with the general deductions of astronomers respecting the distances and magnitudes of the sun and planets, from the following considerations: 1. *The general agreement of all modern astronomers as to these deductions.* However much astronomers may differ in regard to certain subordinate opinions or conjectures respecting certain phenomena, they all agree with respect to the bulks and distances of the planetary orbs, and the mode by which they are ascertained. If there were any fallacy in their calculations, such is the tendency of human nature to find fault, it would soon be pointed out. 2. The consideration of *the accuracy with which astronomers predict certain celestial phenomena* should induce persons unskilled in this science to rely on the conclusions deduced by astronomers. They are fully aware that the eclipses of the sun and moon are calculated and predicted with the utmost accuracy. The very moment of their beginning, middle, and end, and the places where they will be visible, are foretold to a nicety; the nature and magnitude of the eclipse, and all the circumstances connected with it, determined; and that, too, for more than a century to come. All the eclipses which have happened of late years were calculated more than half a century ago, and are to be found recorded in the writings of astronomers. They can likewise tell when Mars, Jupiter, or Saturn is to suffer an occultation by the moon, the time when it will begin and end, the particular part of the moon's limb behind which the planet will disappear, the point on the opposite limb where it will again emerge, and the places of the earth where the occultation will be visible. They can likewise predict the precise moment when any of the fixed stars—even those invisible to the naked eye—shall suffer an occultation by the moon or by any of the planets; and such occultations of the stars and

planets are stated in the "Nautical Almanac," and similar publications, three or four years before they actually happen.

The precise time, likewise, when the planets Mercury and Venus will appear to pass across the sun's disk, has been predicted for a century before such events happened, and such transits have been calculated for several centuries to come, and will most assuredly take place, as they have hitherto done, if the laws of nature continue to operate as in ages past. Dr. Halley, in 1691, predicted the transit of Venus that happened in 1761, seventy years before it took place; and not only so, but he calculated the precise hour in which the planet would appear to touch the limb of the sun as seen from different places; the particular part of the sun's margin where the planet would appear and disappear, and the precise course it would take in passing across the disk of the sun; the appearance it would present in different regions of the globe, and the most proper places in both hemispheres were pointed out where either its beginning, middle, or end would be most distinctly observed, in order to accomplish the object in view; namely, the determination of the exact distance of the sun. All which calculations and predictions were ultimately found to be correct; and astronomers were sent to different parts of the globe to observe this interesting phenomenon, which happens only once or twice in the course of a century. The same astronomer calculated the period of a comet, distinguished by the name of "Halley's Comet," and predicted the periods when it would return. It was seen in England in 1682, and Dr. Halley calculated that it would again appear in this part of the system in 1758; and it accordingly made its appearance in December, 1758, and arrived at its perihelion on the 13th of March, 1759. The validity of these calculations and predictions has been again verified by the reappearance of the same comet in 1835, just at the time when it was expected, which proves that it completes its course in the period which had been predicted, namely, seventy-six years, and will, doubtless, again revisit this part of the system in the year 1911 or 1912. Astronomers can likewise point out, even in the daytime, the different stars and planets which are above the horizon, though invisible to the unassisted eye. I have sometimes surprised even gentlemen of intelligence by showing them, through an equatorial telescope, the star *Arcturus*, and, in a minute or two

afterward, the star *Altair* in another part of the heavens, and the planet Venus in another quarter in the form of a brilliant crescent, while the sun was several hours above the horizon, and shining in its greatest brightness, and while these bodies are every moment shifting their apparent positions; all which is quite easy to be accomplished by every one who understands the motions of the heavenly bodies and the first principles of astronomy.

Now as the above facts are indisputable, and every one who feels an interest in the subject may satisfy himself as to their reality, it is evident to a demonstration that the principles of science on which such calculations and predictions proceed are not mere conjectures or precarious suppositions, but have a real foundation in the constitution of nature and in the fundamental laws which govern the universe. And as the knowledge of astronomers cannot be questioned in relation to the phenomena to which I refer, it would be unreasonable, and injurious to the moral characters of such men, to call in question their modes of ascertaining the distances of the sun and the planetary bodies, and the deductions they have made in relation to their astonishing magnitudes. There is no science whose principles are more certain and demonstrable than those of astronomy. No labour or expense has been spared to extend its observations, and to render them accurate in the extreme; and the noblest efforts of genius have been called forth to establish its truths on a basis immutable as the laws of the universe; and, therefore, the man who questions the leading facts and deductions of this science only proclaims his own imbecility and ignorance.

CHAPTER VIII.

ON THE SCENERY OF THE HEAVENS, AS VIEWED FROM THE SURFACES OF THE DIFFERENT PLANETS AND THEIR SATELLITES.

This is a department of descriptive astronomy which is seldom noticed in books professedly written to illustrate the objects of this science. It is here introduced not only as an

interesting subject of contemplation, but as an illustration of the *variety* which the Creator has introduced into the scenes of the universe, and as a collateral or presumptive argument in support of the doctrine of a plurality of worlds.

Before proceeding to the particular descriptions I intend to give, it may be proper to state the following *General Remarks:* 1. The different clusters of stars or the *constellations* will appear exactly the same when viewed from the other planets as to the inhabitants of our globe. For example, the constellations of *Orion* and of the *Great Bear* will appear of the same shape or figure, and all the stars of which they are composed will appear to have the same arrangement and the same relative distances from each other and from neighbouring stars, as they do to us. 2. The *apparent magnitudes* of the fixed stars will appear exactly the same as they do when viewed from our world; that is, they will appear no larger than shining points of different magnitudes, even when viewed from the most distant planets. The reason of this and of the preceding position is obvious from the consideration of the *immense distance* of those bodies; for although we are 190 millions of miles nearer some of the fixed stars at one time of the year than at another, yet there appears no sensible difference in their size or arrangement, and although we were placed on the remotest planet of the system, we have no reason to believe that any material difference in this respect would be perceived; for the distances of the remoter planets bear no sensible proportion to the distances of the fixed stars. Even the distance of the planet Uranus, great as it is, which would require four hundred years for a cannon ball to move over the space which intervenes between that orb and us, is less than the ten thousandth part of the distance of the nearest star; and, therefore, can produce no sensible difference in the general aspect of the starry firmament. 3. Though the general arrangement of the stars and constellations will appear the same as to us, yet the different directions of the axes of some of the planets from that of the earth *will cause a different appearance in their apparent diurnal revolutions.* Some stars which appear in our equator may, in other planets, appear near one of their poles, and our pole star may appear near their equator.

In the following descriptions it is taken for granted that the general laws of vision are materially the same in all the plan-

etary bodies as in that part of the system which we occupy. Of this we have no reason to doubt, as the same identical light which illuminates the earth likewise enlightens all the planets and their satellites. It originates from the same source, it is refracted and reflected by the same laws, and must produce colours similar or analogous to those which diversify the surface of our globe; though, perhaps, susceptible of numerous modifications in other regions, according to the nature of the atmospheres through which it passes, and the quality of the objects on which it falls. The descriptions that follow likewise proceed on the supposition that the *extent of vision* is the same as ours. This, in all probability, is not the case. It is more probable that, in certain worlds, the organs of vision of their inhabitants may be far more exquisite than ours, and capable of surveying with distinctness a much more extensive range of view. But as we are ignorant of such particulars, we can only proceed on the assumption of what would appear to eyes constituted like ours were we placed on the surfaces of the different planets.

Scenery of the Heavens from the Planet Mercury.—This planet being so near the sun has prevented us from discovering various particulars which have been ascertained in relation to several of the other planets; and, therefore, little can be said respecting its celestial scenery. The starry heavens will appear to move around it every twenty-four hours, as they do to us, if the observations of M. Schroeter, formerly stated (p. 68), be correct; but the direction of its axis of rotation is not known, and, therefore, we cannot tell what stars will appear near its equator or its poles. The sun will present a surface in the heavens seven times as large as he does to us, and, of course, will exhibit a very august and brilliant appearance in the sky, and will produce a corresponding brightness and vividness of colour on the objects which are distributed over the surface of the planet. Both Venus and the earth will appear as *superior* planets; and when Venus is near its opposition to the sun, at which time it will rise when the sun sets, it will present a very brilliant appearance to the inhabitants of Mercury, and serve the purposes of a small moon, to illuminate the evenings in the absence of the sun. As Venus presents a full enlightened hemisphere at this period to the inhabitants of Mercury, it will exhibit a surface six or seven times larger than it does to us when it shines with its great-

est brilliancy, and, therefore, will appear a very bright and conspicuous object in the firmament of this planet. At all other times it will appear at least two or three times larger than it ever does as seen from the earth. It will generally appear round; but at certain times it will exhibit a gibbous phase, as the planet Mars frequently does to us. It will never appear to the inhabitants of Mercury in the form of a crescent or a half moon, as it sometimes does through our telescopes. There is no celestial body within the range of this planet with which we are acquainted which will exhibit either a half moon or a crescent phase, unless it be accompanied with a satellite. The earth is another object in the firmament of Mercury which will appear next in splendour to Venus. The earth and Venus are nearly of an equal size, Venus being only 130 miles less in diameter than the earth; but the earth being nearly double the distance of Venus from Mercury, its apparent size, at the time of its opposition to the sun, will be only about half that of Venus. The earth, however, at this period, will appear in the sky of Mercury of a size and splendour three or four times greater than Venus does to us at the period of its greatest brilliancy. Our moon will also be seen like a star accompanying the earth, sometimes approaching to or receding farther from the earth, and sometimes hidden from the view by passing across the disk of the earth or through its shadow. It will probably appear about the size and brightness of Mars or Saturn, as seen in our sky. The earth with its satellite, and Venus, will be seen near the same point of the heavens at the end of every nineteen months, when they will for some time appear the most conspicuous objects in the heavens, and will diffuse a considerable portion of light in the absence of the sun. At other periods, the one will rise in the eastern horizon as the other sets in the western; so that the inhabitants of Mercury will seldom be without a conspicuous object in their heavens, diffusing a lustre far superior to that of any other stars or planets. The earth will be in opposition to the sun every four months, and Venus after a period of five months. The planets Mars, Jupiter, and Saturn will appear nearly as they do to us, but with a somewhat inferior degree of magnitude and brilliancy, particularly in the case of Mars. The period of the annual revolution of Mercury being eighty-eight days, the sun will appear to move from west to east through the circle of the heavens

at a rate more than four times greater than his apparent motion through the signs of our zodiac.

Appearance of the Heavens as viewed from Venus.—To the inhabitants of this planet the heavens will present an aspect nearly similar to that of Mercury, with a few variations. Mercury will be to Venus an *inferior* planet, which will never appear beyond thirty-eight or forty degrees of the sun. It will appear in the evening after sunset for the space of two or three hours when near its elongation, and in the morning before sunrise when in the opposite part of its course, and will alternately be a morning and an evening star to Venus, as that planet is to us, but with a less degree of splendour. The most splendid object in the nocturnal sky of Venus will be the *earth*, when in opposition to the sun, when it will appear with a magnitude and splendour five or six times greater than either Jupiter or Venus appears to us at the time of their greatest brilliancy. It will serve, in a great measure, the purpose of a moon to Venus, if this planet have no satellite, and will cause the several objects on its surface to project distinct and well-defined shadows, as our moon does when she appears a crescent. Our moon, in its revolutions round the earth, will likewise appear a prominent object in the heavens, and will probably appear about the size that Jupiter appears to us. Her occultations, eclipses, and transits across the earth's disk will be distinctly visible. With telescopes such as the best of ours the earth would appear from Venus a much larger and more variegated object than any of the planets do to us when viewed with high magnifying powers. The forms of our different continents, seas, and islands, the different strata of clouds in our atmosphere, with their several changes and motions, and the earth's diurnal rotation, would, in all probability, be distinctly perceived. Even the varieties which distinguish the surface of our moon would be visible with telescopes of high magnifying power. The circumstances now stated prove the connexion of the different parts of the planetary system with one another, and that the Creator has so arranged this system as to render one world, in a certain degree, subservient to the benefit of another. The earth serves as a large and splendid moon to the lunar inhabitants; it serves, in a certain degree, the purpose of a small moon to Mercury; it serves the purpose of a larger moon, by exhibiting a surface and a radiance four times greater to the

inhabitants of Venus; and it serves as a morning and an evening star to the planet Mars. So that, while we feel enjoyment in contemplating the moon walking in brightness, and hail with pleasure the morning star as the harbinger of day, and feel a delight in surveying those nocturnal orbs through our telescopes, the globe on which we dwell affords similar enjoyments to the intellectual beings in neighbouring worlds, who behold our habitation from afar as a bright speck upon their firmament, diffusing amid the shades of night a mild degree of radiance. From Venus the planets Saturn and Jupiter will appear nearly as they do to us, but the planet Mars will appear considerably smaller. The sun in this planet will present a surface twice as large as he does in our sky, and will appear to make a revolution round the heavens in the course of seven months and a half, which completes the year of Venus.

The Heavens as viewed from Mars.—From this planet the earth will at certain periods be distinctly seen, but it will present a different aspect both in its general appearance and its apparent motions from what it does to the inhabitants of Venus. To Mars the earth is an inferior planet, whose orbit is *within* the orbit of Mars. It will, therefore, be seen only as a morning and an evening star, as Venus appears to us; but with a less degree of magnitude and brightness, since Mars is at a greater distance from the earth than the earth is from Venus. It will present to Mars successively the form of a *crescent*, a *half moon*, and a *gibbous* phase, but will seldom or never be seen as a full enlightened hemisphere, on account of its proximity to the sun, when its enlightened surface is fully turned towards the planet; nor will it ever appear farther removed from the sun, either in the mornings or evenings, than forty-eight degrees, so that the earth will never appear in the firmament of Mars about midnight. The earth will likewise be sometimes seen to pass across the sun's disk like a round black spot, as Venus and Mercury at certain periods appear to us; but the planet Mercury will never be seen from Mars on account of its smallness and its nearness to the sun; for at its greatest elongation it will be only a few degrees from the sun's margin, and will consequently be immersed in his rays. The only time in which it might happen to be detected will be when it makes a transit across the solar disk. Venus will be as seldom seen by the inhabitants of Mars as Mercury is to us. Our

moon will likewise be seen from Mars like a small star accompanying the earth, sometimes appearing to the east and sometimes to the west of the earth, but never at a greater distance from each other than fifteen minutes of a degree, or about half the apparent breadth of the moon; and with telescopes such as ours all its phases and eclipses might be distinctly perceived. The planets Jupiter and Saturn will appear to Mars nearly as they do to us. At the time of Jupiter's opposition to the sun that planet will appear a *slight degree* larger, as Mars is then fifty millions of miles nearer it than we are; but Saturn will not appear sensibly larger than to us; and it is likely that the planets Uranus, Vesta, Juno, Ceres, and Pallas will not be more distinguishable than they are from our globe. The point *Aries*, on the ecliptic of Mars, or one of the points where its ecliptic and equator intersect each other, corresponds to 19° 28′ of our sign *Sagittarius*. In consequence of this, the poles of Mars will be directed to points of the heavens considerably different from our polar points, and its equator will pass through a different series of stars from that which marks our equator, which will cause the different stars and constellations in their apparent diurnal revolution to present a different aspect from what they do in their apparent movements round our globe.

The Heavens as viewed from Vesta, Juno, Ceres, and Pallas.—These planets, being so very nearly at the same mean distance from the sun, the appearance of the heavens will be nearly the same to the inhabitants (if any) of each of these bodies. The planet Jupiter will be the most conspicuous object in the nocturnal sky of all these planets, and will appear with nearly three times the size and splendour that he does when seen from the earth, so as to exhibit the appearance of a small brilliant moon. Saturn will appear somewhat larger and brighter than to us, but the difference in his appearance will be inconsiderable; nor will Uranus be more distinctly visible than from the earth. At other times, when near their conjunction with the sun, these planets will appear smaller than to us. Mars will sometimes appear as a morning and an evening star, but he will always be in the immediate neighbourhood of the sun, and will present a surface much less in apparent size than he does to the earth. The earth will seldom be seen on account of its proximity to the sun; and Venus and Mercury will be altogether invisible, unless when

they transit the solar disk. It is likely that, at certain times, the planets Vesta, Juno, Ceres, and Pallas will exhibit an uncommon, and occasionally a brilliant appearance in the firmament of each other. As their distances from the sun are so nearly the same, they may occasionally approach each other so as to be ten times nearer to one another in one part of their course than at another. It is even possible that they might approach within a few miles of each other, or even come into collision. These different positions in which they may be placed in relation to one another will doubtless produce a great variety in the appearances they present in their respective firmaments; so that at one time they may present in the visible firmament a surface a hundred or even two hundred times greater than they do in other parts of their annual revolutions. It is probable, therefore, that the diversified aspects of these planets, in respect to each other, will form the most striking phenomena which diversify their nocturnal heavens. In consequence of the great eccentricity of the orbit of Pallas, the sun will appear much larger to this planet in one part of its revolution than it does at another.

Celestial Scenery from Jupiter.—The only planet whose appearance will be conspicuous in the firmament of Jupiter is the planet *Saturn*, which will appear with a surface four times greater than is exhibited in our sky, and will appear larger than either Jupiter or Venus does to us, particularly at the time of its opposition to the sun. At certain other periods, when near the time of its conjunction with the sun, it will appear considerably smaller than when viewed from the earth; as, at such periods, Saturn is nearly fourteen hundred millions of miles distant from Jupiter, while it is never beyond ten hundred millions from the earth, even at its remotest distance. The planet Uranus, which is scarcely visible to our unassisted sight, will not be much more distinguishable at Jupiter than with us, even at the period of its opposition, although Jupiter is at that time 400,000,000 of miles nearer it than a spectator on the earth. At other times, when near its conjunction with the sun, it will be 2,300,000,000 of miles from Jupiter, which is 400,000,000 of miles more distant than it ever is from us. Mars will scarcely be seen from Jupiter, both on account of his smallness and his proximity to the sun; for at his greatest elevation he can never be more than eighteen degrees from that luminary. The earth, too, will be invisible from Jupiter

both on account of its small size, its distance, and its being in the immediate vicinity of the sun, and immersed in its rays; so that the inhabitants of this planet will scarcely suspect that such a globe as that on which we dwell exists in the universe. It is a humiliating consideration to reflect, that before we have passed over one fourth part of the extent of our system, this earth, with all its kingdoms and fancied grandeur, of which mortals are so proud, vanishes from the sight, as if it were a mere atom in creation, and is altogether unnoticed and unknown. It is calculated to convey a lesson of *humility* and of humanity to those proud and ambitious mortals who glory in their riches, and in the small patches of earthly territory they have acquired at the expense of the blood of thousands of their fellow-men, and who fancy themselves to be a species of demigods, because they have assisted in the conquest of nations, and in spreading ruin and devastation over the earth. Let us wing our flight to Jupiter or Saturn, which appear so conspicuous in our nocturnal sky, and before we have arrived at the middle point of the planetary system this globe on which we tread, with all the proud mortals that dwell upon its surface, vanishes from the sight as a particle of water, with its microscopic animalculæ, dropped into the ocean, disappears for ever. In those regions more expansive and magnificent scenes open to view, and their inhabitants, if ever they have heard of such beings as fallen man, look down with an eye of pity and commiseration, and view their characters and conduct with a holy indignation and contempt.

Venus and Mercury will, of course, be altogether invisible from the surface of Jupiter, and it is questionable whether even the planets Vesta, Juno, Ceres, and Pallas will be perceived. But although so few of the primary planets are seen in the nocturnal sky of this planet, its firmament will present a most splendid and variegated aspect by the diversified phases, eclipses, and movements of the satellites with which it is encircled; so that its inhabitants will be more charmed and interested by the phenomena presented by their own moons than by their contemplation of the other bodies of the system. But as I have already described the appearances of these moons, as seen from Jupiter (p. 276, chap. iv., sec. ii.), it is unnecessary to enlarge.

Scenery of the Heavens as viewed from Saturn.—The firmament of Saturn will unquestionably present to view a

more magnificent and diversified scene of celestial phenomena than that of any other planet of our system. It is placed nearly in the middle of that space which intervenes between the sun and the orbit of the remotest planet. Including its rings and satellites, it may be considered as the largest body or system of bodies within the limits of the solar system; and it excels them all in the sublime and diversified apparatus with which it is accompanied. In these respects Saturn may justly be considered as the sovereign among the planetary hosts. The prominent parts of its celestial scenery may be considered as belonging to its own system of rings and satellites, and the views which will occasionally be opened of the firmament of the fixed stars; for few of the other planets will make their appearance in its sky. Jupiter will appear alternately as a morning and an evening star, with about the same degree of brilliancy it exhibits to us; but it will seldom be conspicuous except near the period of its greatest elongation, and it will never appear to remove from the sun farther than thirty-seven degrees, and, consequently, will not appear so conspicuous, nor for such a length of time, as Venus does to us. Uranus is the only other planet which will be seen from Saturn, and it will there be distinctly perceptible, like a star of the third magnitude, when near the time of its opposition to the sun. But near the time of its conjunction it will be completely invisible, being then eighteen hundred millions of miles more distant than at the opposition, and eight hundred millions of miles more distant from Saturn than it ever is from the earth at any period. All the other eight planets, together with our moon, will be far beyond the reach of a spectator in Saturn, unless he be furnished with organs of vision far superior to ours in their "space-penetrating power." It is not improbable that more *comets* will be seen in their course from the sun, from the distant regions in which Saturn moves, than from that part of the system in which we are placed. Some of these bodies, when they pass beyond the limits of our view, will be visible beyond the orbit of Saturn; and as their motions in those distant spaces are much slower than when near the sun, they will remain visible for a longer time, when they happen to make their appearance, than they do when passing through our part of the system.

Having already given a pretty full description of the appearance of the rings of this planet as viewed from its sur-

face (p. 195–203), and of the phenomena exhibited by its satellites (p. 283), it is unnecessary to introduce the subject in this place. I shall only remark further, in regard to tho rings which encompass this planet, that, besides the light they reflect on the planet, and the brilliant aspect they present in its firmament, they cast a great diversity of shadows upon the surface of the planet, of different breadths at different times and places, and it will require a considerable degree of attention and investigation on the part of its inhabitants to determine whence the shadows proceed. For when the dark sides of the rings are turned towards them, they will, in all probability, be invisible in their sky, as the dark side of the moon or of Venus is to us; and, therefore, they may be at a loss, in some instances, to discover the causes of such varieties of light and shade. For, although *we* are placed in a convenient position to perceive that they are in reality *complete rings* which environ the body of Saturn, yet it will not be so easy for *its inhabitants* to discover this fact; as only a portion of the rings will be visible in some places, and in the regions near the poles they will appear only like a bright streak in the horizon. They will naturally conclude that the shadows proceed from some body in their firmament; but they will require to make a great variety of observations, to compare them together, and to investigate the doctrine of parallaxes, before they come to the conclusion that the phenomena alluded to are caused by mighty rings which encompass their habitation.

As the diameter of Saturn is ten times the diameter of the earth, it will be comparatively easy for its inhabitants to find the parallaxes, distances, and magnitudes of its different satellites, and likewise of Jupiter and Uranus, which are the only planets visible from Saturn. To those who dwell in its equatorial regions, the motion of the rings around their axes will furnish an accurate measure of time, as well as the diurnal rotation of the planet; and to all places on its surface the periodical revolutions of its different satellites will afford various measures, divisions, and subdivisions of the lapse of duration. The sun will appear from this planet of a size about five times the diameter which Jupiter presents to our view, or about 1-9 or 1-10 part of the diameter of the sun as seen from the earrh; but, notwithstanding, there appears no deficiency of light on the surface of Saturn.

Let us, then, suppose two mighty arches in Saturn's nocturnal sky, appearing to the inhabitants of one region like broad semicircles of light extending completely across the heavens, to other regions like large segments of an arch, the highest point of which elevated only twenty or thirty degrees above the horizon, and to the places adjacent to the polar regions as a zone of light hovering in the horizon; let us suppose the distant stars twinkling through the dark space which separates the rings; the sun eclipsed at noon, in one place, by the upper edge of the rings, and in another place by the lower; the brightness of this luminary waxing dimmer and dimmer, and in a few hours hidden by an invisible object, not to appear again till after a lapse of fourteen years; and the inhabitants of this region of shadows occasionally travelling to those countries where the rings are enlightened and the sun is constantly shining: let us suppose one moon, nine times as large in apparent size as ours, suspended in the canopy of heaven; another, three times as large as ours, in another quarter of the sky; a third twice as large; a fourth about the apparent size of our moon; and a fifth, sixth, and seventh of different apparent magnitudes; some of them appearing with a crescent, some with a gibbous phase, and others with a full enlightened hemisphere; some rising, some setting; one entering into an eclipse, and another emerging from it: let us suppose such scenes as these, and we may acquire a general idea of the phenomena presented in the heavens of Saturn.

Scenery of the Heavens in Uranus.—The orbit of this planet, so far as we know, forms the extreme boundary of the planetary system. Being so far removed from the centre of the system, almost all the other planets and their satellites will be invisible to a spectator placed on this orb. The only planet which will be distinctly visible is Saturn, which will be seen occasionally as a morning and an evening star, and will appear nearly of the same size as to us; but as it will always be seen in the immediate neighbourhood of the sun, it will only be visible at certain distant periods, or intervals of fifteen years, and will appear about as near to the sun as Mercury does when viewed from the earth. Its rings and satellites might occasionally be perceived with such instruments as our best telescopes when it is near the points of its greatest elongation. It is not probable that Jupiter will be visi-

ble from this planet on account of its proximity to the sun. If ever it be visible, it will only be for a short time, after periods of six or eight years have elapsed. From Uranus it is likely that the motions of some of the comets will be seen to advantage, and for a considerable length of time, as the motions of these bodies must be comparatively slow in those distant regions. It is not improbable that, in their course from the sun, the motions of some of these bodies may be followed to the extreme point of their trajectories, and their courses traced in their return towards the central luminary; and that they may be visible in the firmament of this planet for months, and even for years together. It is likewise probable that, from Uranus, the parallax of the nearest fixed stars, and, consequently, their *distance*, may be ascertained. For the diameter of its orbit, which is 3,600,000,000 of miles, will form a pretty extensive *base line* for this purpose, and will produce a parallax nineteen times greater than that of the diameter of the earth's annual orbit, which is only 190 millions of miles. But the determination of such a parallax would require a series of observations made at intervals of forty-two years, namely, at two opposite points of the orbit of Uranus, in moving between which it occupies a space of nearly forty-two years.

The most splendid and interesting scenery in the firmament of this planet will be produced by the phases, eclipses, revolutions, and various aspects of its moons. Six of these bodies have been discovered revolving around it, and it is not improbable that several more (perhaps three or four) may be connected with this distant orb, the smallness of which, and their nearness to the planet, may for ever prevent them from being detected by our most powerful instruments. Let us suppose, then, one satellite presenting a surface in the sky eight or ten times larger than our moon; a second five or six times larger; a third three times larger; a fourth twice as large; a fifth about the same size as the moon; a sixth somewhat smaller; and, perhaps, three or four others of different apparent dimensions: let us suppose two or three of these, of different phases, moving along the concave of the sky, at one period four or five of them dispersed through the heavens; one rising above the horizon, one setting, one on the meridian, one towards the north, and another towards the south; at another period five or six of them displaying their

lustre in the form of a half moon or a crescent in one quarter of the heavens, and at another time the whole of these moons shining, with full enlightened hemispheres, in one glorious assemblage, and we shall have a faint idea of the beauty, variety, and sublimity of the firmament of Uranus. What is deficient in respect of the invisibility of the other planets is amply compensated by its assemblage of satellites, which illuminate and diversify its nocturnal sky. Although this planet is more than seventeen hundred millions of miles nearer some of the fixed stars than we are, yet those luminaries will not appear sensibly larger, as seen from Uranus, than they do from our globe. For even this immense interval would not subtend an angle of nineteen seconds, or the 1-190 part of a degree, as seen from the nearest star; and, of course, all the constellations will present the same figures and relative aspects as they do to us, with this difference only, that those stars which are near our equator or tropics may be near the poles or polar circles of Uranus. This depends entirely upon the position of its axis of rotation, which is to us unknown. The sun will appear so small from this planet, that its apparent diameter will not exceed 2½ times the apparent diameter of Jupiter; but its light is not so weak as we might be apt to imagine from this circumstance, as is evident from the brightness it exhibits when viewed with a telescope in the nighttime, and likewise from the well-known phenomenon that when the sun is eclipsed to us, so as to have only the *one fortieth* part of its disk left uncovered by the moon, the diminution of light is not very sensible; and it has been frequently noticed that, at the end of the darkness in total eclipses, when the sun's western limb begins to be visible, and seems no bigger than a thread of fine silver wire, the increase of light is so considerable, and so quickly illuminates all surrounding objects, as to strike the spectators with surprise. But whatever deficiency of light there may be on this planet, we may rest assured, from a consideration of the *wisdom* and benevolence of the Creator, that this deficiency is amply compensated, either by the objects on which it falls being endowed with a strong reflective power, or by the organs of vision being adapted to the light received, or by some other contrivances with which we are unacquainted.

SCENERY OF THE HEAVENS AS SEEN FROM THE SATELLITES.

Celestial Scenery of the Moon.—Although the moon is the nearest body to the earth, and its constant attendant, yet its celestial phenomena will, in a variety of respects, be very different from ours. The earth will appear to be the most splendid orb in its nocturnal sky, and its various phases and relative positions will form a subject of interesting inquiry and contemplation to its inhabitants. It will present the appearance of a globe in the sky *thirteen times larger* than the moon does to us, and will diffuse nearly a corresponding portion of light on the mountains and vales on the lunar surface. As the moon always presents nearly the same side to our view, so the earth will be visible to only one half of the lunar inhabitants. Those who live on the opposite side of the moon, which is never turned towards our globe, will never see the earth in the sky unless they undertake a journey to the opposite hemisphere for this purpose ; and those who dwell near the central parts of that hemisphere which is turned from our globe will require to travel more than 1500 miles before they can behold the large globe of the earth suspended in the sky. To all those to whom the earth is visible, it will appear *fixed* and immoveable in the same relative point of the sky, or, at least, will appear to have no circular motion round the heavens. To a spectator placed in the middle of the moon's visible hemisphere, the earth will appear directly in the zenith or over head, and will always seem to be fixed very nearly in that position. To a spectator placed in any part of the extremity of that hemisphere, or what seems to us to be the margin of the moon, the earth will appear always nearly in the horizon ; and to spectators at intermediate positions the earth will appear at higher or lower elevations above the horizon, according to their distance from the extremities or the central parts of that hemisphere. But, although the earth appears fixed nearly in the same part of the sky, there is a slight variation produced by what is termed the *libration* of the moon (see p. 251), by which it appears to turn occasionally a small portion of its hemisphere towards the earth. In consequence of this libration the earth will appear now and then to shift its position a little by a kind of vibratory motion, so that those at the extremities of the hemisphere, who see the earth in their horizon, will sometimes

see it dip a little below, and at other times rise a little above their horizon. This vibratory motion they will probably be disposed, at first view, to attribute to the earth, which they will naturally consider as a body nearly at rest, but subject to a vibratory movement like that of a pendulum, whereas this apparent vibration proceeds from the moon itself.

The earth is continually shifting its *phases* as seen from the moon. When it is *new moon* to us it is *full moon* to the lunar inhabitants, as the hemisphere of the earth next the moon is then fully enlightened; so that, at the time when the sun is absent, they enjoy the effulgence of a full moon thirteen times larger than ours. When the moon is in the first quarter to us, the earth is in the third quarter to them; and, in every other case, the phases of the earth are exactly opposite to those which the moon presents to us (see p. 250). The earth passes through all the phases of the moon in the course of a month; but the *progress* of these phases will be more regularly and accurately perceived than that of the moon's phases are by us. When it is night in the moon, and the nights there are a fortnight long, the inhabitants see at first only a small part of the earth enlightened, like a slender crescent; then a larger and a larger portion, till at length it becomes entirely luminous. During the whole of these changes the earth is every moment visible, and apparently fixed in the same immoveable position; and as there are no clouds in the lunar atmosphere, the view of the earth and of the variation of its phases will never be interrupted; whereas these changes in the moon are visible to us only from one night to another, and, by the interposition of clouds, the moon is frequently hidden from our view for seven or eight days together. By means of the light thus diffused by the earth upon the moon, it so happens that the side of the moon next the earth is never in darkness; for, when the sun is absent, the earth shines in the firmament with a greater or less degree of splendour; but when the sun is absent from the other hemisphere, the inhabitants have no light but what is derived from the stars and planets. It is probable, however, that the light of these luminaries is more brilliant as seen from the moon than from the earth, as the lunar atmosphere is more pure and transparent than that of the earth, and as no clouds or dense vapours exist in it to intercept the rays of those distant orbs; and the stars and planets will constantly shine in the firmament of

that hemisphere of the moon with undiminished lustre. Perhaps, too, there may be some arrangement for providing additional light to that hemisphere in the absence of the sun, either by the coruscations of some phosphoric substance, or by something analogous to our aurora borealis.

Whether the earth will throw as much light upon the moon, *in proportion to its size*, as the moon diffuses upon the earth, is somewhat doubtful. I am disposed to think that the greater part of the surface of the terraqueous globe will not reflect so much light, in proportion to its bulk, as the general surface of the moon; for, as the greater part of the earth is covered with water, and as water absorbs a considerable portion of the rays of light, the seas and ocean will present a more dark and sombre aspect than any part of the lunar orb presents to us; but it is highly probable that the continents and islands will exhibit a lustre nearly equal to that of the mountainous regions of the moon.

Although the earth will seem nearly fixed in one position, yet *its rotation round its axis will be distinctly perceptible*, and will present a variety of different appearances. Europe, Asia, Africa, and America will present themselves one after another in different shapes, nearly as they are represented on our maps and globes; and the regions near our poles, which we have never yet had it in our power to explore, will be distinctly seen by the lunarians, who will be enabled to determine whether they chiefly consist of land or of water. The several continents, seas, islands, lakes, peninsulas, plains, and mountain ranges, will appear like so many spots, of different forms and degrees of brightness, moving over its surface. When the Pacific Ocean, which occupies nearly half the globe, is presented to view, the great body of the earth will assume a dusky or sombre aspect, except towards the north, the northeast, and northwest; and the islands connected with this ocean will exhibit the appearance of small lucid spots on a dark ground. But when the eastern continent turns round to view, the earth (especially its northern parts) will appear to shine with a greater degree of lustre. These appearances will be diversified by the numerous strata of clouds which are continually carried by the winds over different regions, and will occasionally intercept their view of certain parts of the continents and seas, or render their appearance more obscure at one time than at another. It is likewise probable that the

occasional storms in tropical climates, and the changes produced in different countries by summer and winter, will cause the earth to present a diversity of aspect to the inhabitants of the moon. The bands of ice which surround the poles will alternately exhibit a kind of lucid circle, while the verdant plains will appear of a different colour and assume a milder aspect. By means of these different spots, the lunarians will be enabled to determine the exact period of the earth's rotation, as we determine that of the sun by the appearance and disappearance of the spots on its surface. And as the period of the earth's rotation never varies, it may serve as a clock or dial for the exact measure of time; and the lesser divisions of this period may be ascertained by the appearance on the margin or the central parts of the earth's hemisphere of certain seas, continents, or large islands, which will constantly appear on certain parts of the earth's disk at regular intervals of time. Through telescopes such as ours, the variegated aspect of the earth in its diurnal motion would present to us, were we placed on the moon, a novel and most interesting appearance.

The apparent diurnal motions of the sun, the planets, and the stars, will appear much slower, and somewhat different in several respects from what they do to us. When the sun rises in their eastern horizon, his progress through the heavens will be so slow that it will require more than seven of our days before he comes to the meridian, and the same time before he descends to their western horizon; for the days and nights of the moon are nearly fifteen days each, and they are nearly of an equal length on all parts of its surface, as its axis is nearly perpendicular to the ecliptic, and, consequently, the sun never removes to any great distance from the equator. During the day the earth will appear like a faint cloudy orb, always in the same position; and during night the stars and planets will be visible, *without interruption*, for fifteen days, and will be seen moving gradually during that time from the eastern to the western horizon. Though the earth will always be seen in the same point of the sky both by day and night, yet it will appear to be constantly shifting its position with respect to the planets and the stars, which will appear to be regularly moving from the east to the west of it, and some of them will occasionally be hidden or suffer an *occultation* for three or four hours behind its body. The sun, planets, and fixed stars will appear exactly of the same apparent magni-

tudes as they do from the earth; but as the poles of the moon are directed to points of the heavens different from those to which the poles of the earth are directed, the pole stars in the lunar firmament, and the stars which mark its equator and parallels, will all be different from ours; so that the stars, in their apparent diurnal revolutions, will appear to describe circles different from those which they describe in our sky. The *inferior* planets Mercury and Venus will generally be seen in the neighbourhood of the sun, as they are from the earth; but they will be more distinctly perceived, and be visible for a much longer period of time after sunset than they are from our globe. This is owing, first, to the transparency of the lunar atmosphere, and the absence of dense vapours near the horizon, which, in our case, prevent any distinct observations of the celestial bodies when at a low altitude; and, secondly, to the slow apparent diurnal motion of these bodies. When Mercury is near its greatest elongation, it will remain above the horizon more than thirty hours after the sun has set, and, consequently, will be visible for a much longer time in succession than it is to us. When Venus is near its greatest elongation, it will be seen, without intermission, either as a morning or an evening star, for a space of time equal to more than three of our days. The *superior* planets, as with us, will be seen in different parts of the heavens, and occasionally in opposition to the sun; but they will appear to be continually shifting their positions with respect to the earth, and in the course of fifteen days will be seen in the very opposite quarter of the heavens, and in other fifteen days will be again in conjunction with the earth; and nearly the same appearances will be observed in reference to the other planets, but the periodic times of their conjunctions with the earth and oppositions to it will be somewhat different, owing to the difference of their velocities in their annual revolutions.

The *eclipses of the sun* which happen to the lunarians will be more striking, and total darkness will continue for a much longer time than with us. When a total eclipse of the *moon* happens to us, there will be a total eclipse of the *sun* to the lunarians. At that time the dark side of the earth is completely turned towards the moon, and the sun will appear to pass gradually behind the earth till it entirely disappears. The time of the continuance of *total darkness* in central eclipses will be nearly two hours; and of course, a total eclipse of

the sun will be a far more striking and impressive phenomenon to the inhabitants of the moon than to us. A complete darkness will ensue immediately after the body of the sun is hidden, and the stars and planets will be as clearly seen as at midnight. When a *partial* eclipse of the moon happens to us, all that portion of the moon's surface over which the shadow of the earth passes will suffer a *total* eclipse of the sun during the period of its continuance. On other parts of the moon's surface there will be a *partial* eclipse of the sun, and to those who are beyond the range of the earth's shadow no eclipse will appear. When an eclipse of the *sun* happens to us, the lunarians will behold a dark spot, with a penumbra or fainter shades around it, moving across the disk of the earth, which then appears a full enlightened hemisphere, excepting the obscurity caused by the progress of the shadow. The inhabitants on the other hemisphere of the moon can never experience a solar eclipse, as the earth can never interpose between the sun and any part of that hemisphere, so that they will only know of such phenomena by report, unless they undertake a journey for the purpose of observing them.

The study of astronomy in the moon will, on the whole, be more difficult and complex than to us on the earth. The phenomena exhibited by the earth will be the most difficult to explain. The lunarians, at first view, will be apt to imagine that the earth is a quiescent body in their firmament, because it appears in the same point of the sky, and that the other heavenly orbs revolve around it. It will require numerous observations of the apparent motions of the sun, the earth, the planets, and the stars, and numerous trains of reasoning respecting the phenomena they exhibit, before they are convinced that the globe on which they dwell really moves round the earth, and that both of them move, in a certain period, around the sun. If they are endowed with no higher powers than man, or if they are as foolish and contumacious as the great bulk of mankind, it will be more difficult to convince them of the true system of the world than it has been for our astronomers to convince a certain portion of our community that the earth turns round its axis, and performs a revolution round the sun. They will naturally think, as we did formerly, that their habitation is in a quiescent state in the centre of the universe, and that all the other bodies in the heavens, ex-

cept the earth, revolve around it; and the singular phenomena which our globe exhibits in their sky, with its diversified aspect, its diurnal rotation, and occasional *vibrations*, will puzzle them not a little in attempting to find out a proper explanation. It will be somewhat difficult for them to ascertain the exact length of their year, or the time of their revolution round the sun. There are only two ways by which we can conceive they will be enabled to determine this point: 1. By observing when either of the poles of the earth begins to be enlightened and the other pole to disappear, which is always at the time of our equinoxes. 2. By observing the course of the sun among the stars, and endeavouring to ascertain when he returns to the same relative position in reference to any of these orbs. The length of the lunar year is about the same as ours, but different as to the number of days, the lunarians having only 12 7-19 days in their year, every day and night being as long as 29 1-2 of ours. On the other hand, the lunar astronomers will enjoy some advantages in making celestial observations which we do not possess. Those who live on the side next the earth will be enabled to determine the *longitude* of places on the lunar surface with as much ease as we find the *latitude* of places on our globe. For as the earth keeps constantly over one meridian of the moon (or very nearly so), the east and west distances of places from that meridian may be readily found, by taking the altitude of the earth above the horizon, or its distance from the zenith, on the same principle as we obtain the latitude of a place by taking the altitude of the pole star, or the height of the equator above the horizon. The lunar astronomers will likewise possess advantages superior to ours in the purity of their atmosphere, and the greater degree of brilliancy with which the heavenly bodies will appear; and, in particular, they enjoy a singular advantage above a terrestrial astronomer in the *length of their nights*, which gives them an opportunity of contemplating the heavenly bodies, particularly Mercury and Venus, and tracing their motions and aspects for a length of time without intermission.

Such are some of the peculiar phenomena of the heavens as beheld from the moon. However different these phenomena may appear from those which are beheld in our terrestrial firmament, they are all owing to the following circumstances: that the moon moves round the earth as the more immediate

centre of its motion; that it turns always the same side to the earth, and, consequently, it moves round its axis in the same time in which it moves round the earth. These slight differences in the motions and relative positions of the earth and moon are the principal causes of all the peculiar aspects of the lunar firmament which we have now described. And this consideration shows us how the Creator may, by the slightest changes in the positions and arrangements of the celestial orbs, produce an indefinite variety of scenery throughout the universe, so that no world or system of worlds shall present the same scenery and phenomena as another. And so far as our knowledge and observation extend, this appears to be one of the grand principles of the Divine arrangements throughout the system of Creation, which will be still more apparent from the sketches I am now about to give of the phenomena presented from the surfaces of the satellites connected with the other planets.

The Scenery of the Heavens from the Satellites of Jupiter.—The scenery of the firmament as beheld from the satellites of this planet will bear a certain analogy to what we have now described in relation to the moon, but it will be much more diversified and resplendent. The most striking and glorious object in the firmament of the *first satellite* is the planet itself. The distance of this satellite from the centre of Jupiter being only about three diameters of that body, it will appear in the heavens like an immense globe, above thirteen hundred times larger than the apparent size of our moon, and will occupy a considerable portion of the celestial hemisphere. To those who live in the middle of the hemisphere of this satellite, opposite to Jupiter, this vast globe will appear in the zenith, filling a large portion of the sky directly above them, equal to 19 degrees of a great circle, so that nine or ten of such bodies would reach from one side of the heavens to another. To those in other situations it will appear at different elevations above the horizon, according to their distances from the central parts of that hemisphere. This huge globe, in the course of twenty-one hours, will exhibit a crescent, a half moon, a gibbous phase, and a full enlightened hemisphere so that its appearance will be perpetually changing. When it shines with a full face, it will exhibit a most glorious appearance: it will reflect an immense quantity of light upon the satellite, and all the varieties on its surface will be beauti-

fully perceived. In the daytime it will present a cloudy appearance, continually changing its form, and when its dark side is turned to the satellite it will probably become invisible; but it will never be altogether invisible beyond two or three hours at a time, till its enlightened crescent again begins to appear. We find by the telescope that the surface of Jupiter is diversified with a variety of belts, which frequently change their appearance, and sometimes by bright and dark spots. Now all the varieties on its surface, and the changes which may take place in its atmosphere, will be pretty distinctly seen from the surface of this satellite; and as Jupiter turns round its axis in the space of less than ten hours, every hour will present a new scene upon its surface. This expansive and variegated surface of Jupiter, its diurnal rotation, and its rapid change of phases, will therefore form a most wonderful and interesting spectacle to the inhabitants of this satellite.

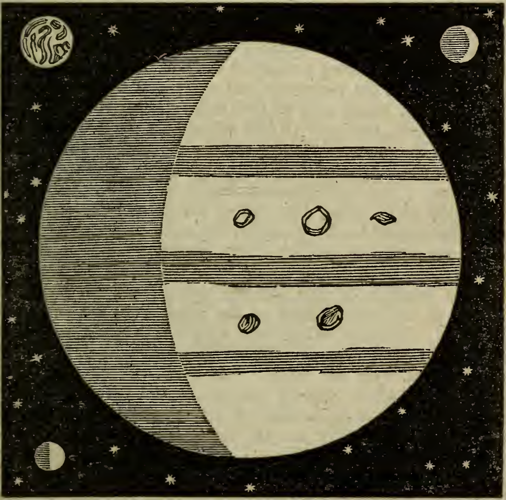
The three other satellites will likewise increase the variety and the lustre of its firmament. The second satellite, in its course round Jupiter, will frequently come within 160,000 miles of the first, which is its nearest approach to it; at which time the satellite will appear with a face nearly three times as large as our moon. At other times it will be 680,000 miles distant, and will appear more than sixteen times smaller than in the former position. At the time when Jupiter presents its dark hemisphere to the first satellite, if the second satellite be then at its nearest distance, or in opposition to the sun, it will shine with a full enlightened hemisphere upon the first satellite. At other times it will assume a half moon, a crescent, or a gibbous phase; and these phases will not only be rapidly changing, but the apparent magnitude of the satellite will likewise be rapidly increasing or diminishing. While at one period it shines with a large and full-enlightened face, in the course of two or three of our days it will appear as a slender crescent, and more than twelve or sixteen times less in apparent diameter than before. The third and fourth satellites will exhibit phenomena somewhat similar; but as their distance is greater than that of the second, their apparent magnitudes will be smaller, and the changes of their phases will be less frequent, in proportion to the slowness of their motions and the length of the periods of their revolutions. The eclipses of the sun, which so frequently happen to the first satellite from the interposition of the body of Jupiter, will

form very interesting and impressive phenomena. Every forty-two hours this satellite suffers a solar eclipse for the space of more than two hours; and it is highly probable that it is chiefly at such times that the starry firmament appears in all its splendour, and affords its inhabitants an opportunity of tracing the motions and contemplating the phenomena of the distant bodies of the universe; for at other times the blaze of reflected light from the body of Jupiter and from the other satellites will, in all probability, prevent the greater part of the fixed stars from being distinctly perceived; so that these eclipses, instead or being an evil or a cause of annoyance to the inhabitants, will increase their enjoyment, will add to the variety of their celestial scenery, and open to them prospects of the grandeur of the starry firmament and the distant regions of creation.

What has been now stated in reference to the first satellite may also be applied in general to the other three satellites, with this difference, that Jupiter will appear of a different apparent magnitude from each satellite; and the motions, magnitudes, and aspects of the other satellites will likewise be somewhat different. In each satellite the great globe of Jupiter, suspended motionless in the sky, will be the most conspicuous object in the heavens. To the *second* satellite this globe will appear about 470 times larger than our moon; to the *third* 180 times; and to the *fourth* about 80 times the apparent surface of the full moon. But each satellite will have certain other phenomena *peculiar to itself*, which it would be too tedious to describe. To all of them the occultations of the other satellites by the body of Jupiter; their eclipses by falling into its shadow; the varieties on its surface, caused by its diurnal rotation; the shadows of the satellites passing like dark spots across its disk; the transits of the satellites themselves, like full moons crossing the orb of Jupiter; the diversified phenomena of eclipses, some of them happening when the satellite is like a crescent or half moon, and some of them when it appears as a full enlightened hemisphere, and various other circumstances, will afford an indefinite variety of celestial phenomena; and scarcely a single day will pass in which some of these phenomena are not observed. The length of the day is different in each satellite. In the first satellite, the length of the day and night is 42 hours 27 minutes; in the second, 3 days, 13 hours; in the

third, 7 days, 3¼ hours; and in the fourth, 16 days, 16½ hours. The starry heavens will therefore appear to make a revolution round each satellite in these respective times. The other satellites will also appear to make a diurnal revolution, but in periods of time somewhat different. The variety of motions, and other phenomena to which we have now alluded, and particularly the rotation of Jupiter and the variation of its phases, will afford various accurate measures of time to all the satellites. The following figure contains a rude sketch of a portion of the firmament as it will appear from one of the satellites of Jupiter.

Fig. CXI.



In this figure, suppose the larger circle at the top to represent one of the satellites as seen in the firmament of the fourth satellite, and suppose it appears with a surface twice

the size of our moon ; Jupiter would require to be double the size here represented, and more than fifteen times larger to represent its comparative size as viewed from the *first* satellite. The larger circle represents Jupiter when exhibiting a gibbous phase to the satellite ; the three other figures are the other satellites under different phases.

Celestial Scenery of the Satellites of Saturn.—What has been stated above in relation to Jupiter's satellites will apply, in part, to those of Saturn. But the satellites of this planet have likewise celestial scenery *peculiar to themselves*, and the scenes presented to one satellite are, in some respects, different from those presented to all the rest. One of the most singular phenomena in their firmament is the diversified appearance of the body of Saturn and that of its rings, which will be beheld in their sky under a great variety of aspects. To describe all the variety of phenomena peculiar to each satellite connected with Saturn would almost require a separate treatise, and therefore I shall state only two or three prominent facts in relation to the *first* and *seventh*, or the innermost and outermost satellites. The first satellite, being only 80,000 miles distant from the *surface* of Saturn, and only 18,000 miles from the outer edge of the rings, the globe of Saturn and its stupendous rings must present a very august and striking appearance in its nocturnal firmament. The hemisphere of Saturn contains an area more than 1300 times larger than that of our moon ; consequently, if the first satellite were placed at the same distance from Saturn as our moon, the surface of that planet would appear, from the satellite, 1300 times larger than the moon does to us. But the satellite is only 120,000 miles from the centre of Saturn, or half the distance of the moon from the centre of the earth ; therefore Saturn will appear four times larger, or 5200 times greater, as seen from this satellite, than the moon when viewed from the earth. The moon occupies only the 1-90,000 part of our celestial hemisphere, but the globe of Saturn will fill the *one seventeenth part* of the visible firmament of its first satellite ; and if we take the extent of the rings into account, they will occupy a space two or three times greater ; so that the planet and its rings will present a most grand and magnificent object in the canopy of heaven, of which we can form only a very faint conception. It is not likely that more than one half of the globe of Saturn will be visible from this satellite on account of the interposition of the rings ; and as it

moves in an orbit which is nearly parallel with the plane of the rings, the surfaces of these rings will be seen in a very *oblique direction;* but still they will exhibit a very resplendent appearance. When the *edge* of the exterior ring is opposite to the satellite, and enlightened by the sun, it will present a large arch of light in the heavens on each side of the planet, above which will appear half the hemisphere of Saturn. If the satellite turn round its axis in the same time in which it revolves round the planet, as is probable, Saturn and its rings will appear stationary in the heavens, and the planet will present to the inhabitants of the satellite a variety of phases, such as a half moon and a crescent, besides the variety of objects which will appear on the surface of Saturn during its rotation on its axis. The rings will likewise appear to vary their aspect during every revolution, besides the variety of objects they will present during their rotation. At one time they will exhibit large and broad luminous arches; at another time they will appear as narrow streaks of light; and at another they will appear like dark belts across the disk of Saturn. And as this satellite moves round the planet in the course of twenty-two and a half hours, these appearances will be changing almost every hour. The appearances of the six other satellites, continually varying their phases, their apparent magnitudes, and their relative aspects; their positions in respect to the body of Saturn and its rings; their occultations by the interposition both of the rings and the planet, and the eclipses to which they are frequently subjected, will produce a diversity of phenomena and a grandeur unexampled in the case of any other moving bodies in our system. The second satellite, when in opposition, or at its nearest position to the first, will be only thirty thousand miles distant; and although its real size is not greater than our moon, it will present a surface sixty-four times larger than the full moon does in our sky. It will appear in all the phases of the moon in the course of less than thirty-six hours, and will be continually changing its apparent magnitude, on account of its removing farther from or nearer to the first satellite. The third satellite* will appear nearly half as large, as it is only seventy thousand miles distant at its nearest approach; and will present nearly the same varieties as the other. All the other satellites will appear smaller in pro-

* Here the satellites are distinguished *according to the order of their distances from Saturn.*

portion to their distance from the orbit of the first; but they will all appear much larger than our moon, except the seventh, or outermost satellite, which will appear considerably smaller. Perhaps the sixth satellite from Saturn will not appear larger than our moon.

The seventh or outermost satellite, which is reckoned among the largest, will have a scenery in its sky somewhat different from that of the first. As its orbit is materially inclined to the rings, its inhabitants will have a more ample prospect of these rings and of the body of Saturn than several of the other satellites, although these objects are beheld at a greater distance, and, consequently, will not fill so large a portion of its sky. Their appearance, however, will not be destitute of splendour; for this satellite is 400 times nearer Saturn than we are, and the body of this planet will appear sixteen times larger than the moon to us, and its rings will occupy a space proportionably more expansive. The phases of Saturn and its rings, and the various changes of aspect which they assume, will be more distinctly perceptible, though on a smaller scale, than from some of the interior satellites; for the whole body of the planet, as well as the rings, will in most cases appear full in view. The other six satellites will be seen in all the different phases and aspects above described, and they will never appear to recede to any great distance from the body of Saturn; but will appear first on one side and then on another, and sometimes either above or below the planet, as Mercury and Venus appear to us in respect to the sun, and, consequently, that portion of the heavens in which Saturn appears will present a most splendid appearance. In this respect the relative positions of the satellites, as seen from the outermost, will be different from their aspects and positions as viewed from the innermost satellite, where they will sometimes appear in regions of the sky directly opposite to Saturn. All the other satellites of this planet will have phenomena *peculiar to themselves* in their respective firmaments, and in all of them these phenomena will be exhibited on a scale of grandeur and magnificence. But to enter into details in reference to each satellite might prove tedious to the general reader.

Let us, then, conceive a firmament in which is suspended a globe five thousand times larger than the apparent size of our moon; let us conceive luminous arches, still more ex-

pansive, surrounding this globe ; let us conceive six moons of different apparent magnitudes, some of them sixty times larger in apparent size than ours ; let us conceive, further, all these magnificent bodies sometimes appearing in one part of the heavens and sometimes in another, changing their phases and apparent magnitudes and distances from each other every hour ; appearing sometimes like a large crescent, sometimes like a small, sometimes shining with a full enlightened face, and sometimes suffering a total eclipse ; sometimes hidden behind the large body of the planet, and sometimes crossing its disk with a rapid motion, like a circular shadow ; let us suppose these and many other diversified phenomena presenting themselves with unceasing variety in the canopy of heaven, and we shall have some faint idea of the grandeur of the firmament as seen from some of the satellites of Saturn.

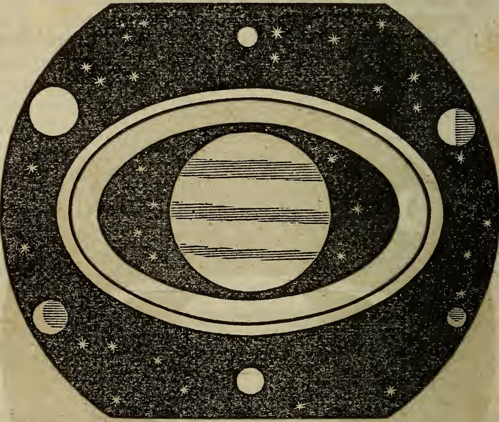
No delineations, except on a very large scale, could convey any tolerable idea of the objects now described. Fig. CXII. exhibits a rude idea of the firmament as viewed from

Fig. CXII.

the first or second satellite of Saturn; but the body of Saturn and the ring should be eight or ten times larger in proportion to the size of the moons or satellites here represented. As the orbits of the inner satellites are nearly on the same plane as the rings, they will appear in an oblique position, and it is questionable whether the division between the rings will be distinctly visible. The opposite part of the ring, or that which is most distant from the satellite, will appear smaller than the side which is nearest it; and only one half of the body of Saturn will be seen, the other half being hidden, either in whole or in part, by the ring.

Fig. CXIII. represents the firmament of the seventh or outermost satellite. As its orbit is considerably inclined to the

Fig. CXIII.



plane of the ring, the whole body of the planet will frequently be seen within the rings, which will appear as ovals around it. The six other satellites will appear in the vicinity of Saturn and its rings, none of them ever removing to any considerable distance from the edge of the rings, and some of them may occasionally be seen moving in the open space between the

planet and the rings. In this figure Saturn and the rings should be considerably larger in proportion to the moons than they are here represented.

Celestial Scenery as viewed from the Rings *of Saturn.*—Supposing the rings to be inhabited, which there is as much reason to believe as that the planet itself is a habitable globe, it is probable that there is a greater diversity of celestial scenery and of sublime objects presented to view than any we have yet described. There will be at least six varieties of celestial scenery, according as the spectator is placed on different parts of the rings. One variety of scene will be exhibited from the *exterior* edge of the outer ring; a second variety from the *interior* edge of the inner ring; a third variety from the interior edge of the *outer* ring; a fourth from the exterior edge of the *inner* ring; a fifth from the *sides* of the rings enlightened by the sun; and a sixth variety from the opposite sides, which are turned away from the sun, and enjoy, for a time, only the reflected light from the satellites. To describe all these varieties in minute detail would be tedious, and at the same time unsatisfactory, without the aid of diagrams and figures on a very enlarged scale, and therefore I shall chiefly confine myself to a general description of one of these celestial views.

Those who live on the sides of the rings will behold the one half of the hemisphere of Saturn, which will fill, perhaps, the one fifth or the one sixth part of their celestial hemiphere, while the other portions of the planet will be hidden by the interposition of the rings. Those who are near the inner edge of the interior ring are only thirty thousand miles from the surface of Saturn, and, consequently, all the varieties upon its surface will be distinctly perceived. Those near the outer edge of the exterior ring are about sixty thousand miles distant from the planet, which will consequently appear to them four times less in size than to the former; but being only eighteen thousand miles from the first satellite at the time of its opposition to Saturn, that satellite will present an object more than three hundred and fifty times larger than our moon, which will rapidly assume different phases, and will be continually varying in its apparent magnitude; and at its greatest distance beyond the opposite side of the rings it will appear at least 170 times less than when in the nearest point of its orbit; and all the intermediate varieties of magnitude and

aspect will be accomplished within less than two days. So that this satellite will be continually changing its apparent size, from an object two or three times the apparent bulk of our moon to one 350 times greater. The same may be affirmed in respect to the other six satellites, with this exception, that they will appear of a smaller magnitude, and the periodic times of their phases and the changes in apparent magnitude will be different.

Another object which will diversify the firmament of those who are on one of the sides of the rings is the opposite portions of the rings themselves. These will appear proceeding from each side of the planet like large broad arches of light, each of them somewhat less than a quadrant, and will fill a very large portion of the sky, so that the inhabitants of the same world will behold a portion of their own habitation forming a conspicuous part of their celestial canopy, and, at first view, may imagine that it forms a celestial object with which they have no immediate connexion. Were they to travel to the opposite part of the ring, they would see the habitation they had left suspended in the firmament, without being aware that the spot which they left forms a portion of the phenomenon they behold. As the rings revolve round the planet, and the planet revolves round its axis, the different parts of the surface of the planet will present a different aspect, and its variety of scenery will successively be presented to the view. The eclipses of the sun and of the satellites, by the interposition of the body of Saturn and of the opposite sides of the rings, will produce a variety of striking phenomena, which will be diversified almost every hour.

From the dark side of the rings, which are turned away from the sun for fifteen years, a great variety of interesting phenomena will likewise be presented ; and, during this period, the aspect of the firmament will in all probability be most vivid and striking. This portion of the rings will not be in absolute darkness during the absence of the sun, for some of the seven satellites will always be shining upon it ; sometimes three, sometimes four, and sometimes all the seven, in one bright assemblage. It is probable, too, that the planet, like a large slender crescent, will occasionally diffuse a mild splendour ; and, in the occasional absence of these, the fixed stars will display their radiance in the heavens, which will be the principal opportunity afforded for

studying and contemplating these remote luminaries. Those who are on the outermost ring will behold the other ring, and the opposite parts of their own, like vast arches in the heavens; and although only 2800 miles intervene between the two rings, that space may be as impassable as is the space which intervenes between us and the moon.

If the two rings have a rotation round Saturn in different periods of time, as is most probable, it will add a considerable variety to the scenery exhibited by the different objects which will successively appear in the course of the rotation.

The numerous splendid objects displayed in the heavens, as seen from these rings, would afford a grand and diversified field for telescopic observations, surpassing in variety and sublimity whatever is displayed in any other region of the solar system; by which some of the objects might be con-

FIG. CXIV.

templated as if they were placed within the distance of forty or fifty miles.

The preceding figure (CXIV.) represents a view of the firmament from one of the sides of the rings, in which is seen half of the hemisphere of Saturn, with a portion of the opposite sides of the rings projecting, as it were, from each side of the planet, the central part being hidden by the interposition of its body. From the inner edge of the interior ring the whole hemisphere of Saturn will be visible. The body of Saturn and the rings should be at least twenty times larger than here represented, so as to be proportionate to the apparent size of the satellites.

Celestial Scenery from the Satellites of Uranus.—After what we have stated respecting the satellites of Jupiter, it would be needless to enter into detail respecting the celestial views from the satellites of this planet, as they will bear a striking analogy to those of the moons of Jupiter; but the firmament of each satellite of Uranus will be more diversified than that of any of the satellites of Jupiter, as there are six satellites connected with this planet, and probably three or four more which lie beyond the reach of our telescopes. From its first satellite the body of Uranus will appear nearly three hundred times larger than the apparent size of the moon in our sky, and, consequently, will appear a very grand and magnificent object in its firmament, while the other five moons, in different phases and positions, will serve both to illuminate its surface and to diversify the scenery of the heavens. To the second satellite Uranus will appear about one hundred and eighty times larger than the moon to us; and to the other satellites it will present a smaller surface in proportion to their distance. Each satellite will have its own peculiarity of celestial phenomena; but after what we have already stated in the preceding descriptions, it would be inexpedient to enter into details. I shall therefore conclude these descriptions with the following remarks:

1. In the preceding descriptions, the *apparent magnitudes* of Jupiter, Saturn, and Uranus, as seen from the satellites, and the apparent magnitudes of the satellites as seen from each other, are only approximations to the truth, so as to convey a *general idea* of the scenes displayed in their respective firmaments; perfect accuracy being of no importance in such descriptions. 2. The variety of celestial phenomena in the

firmaments of these bodies is much greater than we have described. Were we to enter into minute details in relation to such phenomena, it would require a volume of considerable size to contain the descriptions; for in the system of Saturn itself there is more variety of phenomena than in all the other parts of the planetary system. 3. Machinery would be requisite in order to convey clear ideas of some of the views alluded to in the preceding descriptions, particularly in relation to the rings and satellites of Saturn, in which the proportional distances and magnitudes of the respective bodies would require to be accurately represented. An instrument of considerable size and complication of machinery would be requisite for exhibiting all the phenomena connected with Saturn; and one of the principal difficulties would be to produce a diurnal rotation of the rings round Saturn, while, at the same time, they had no immediate connexion with it, and while their *thickness* was no greater in proportion to their breadth than what is found in nature, which is only about the one three hundredth part of the breadth of the two rings, including the empty space between them. 4. The diversity of celestial scenery to which we have alluded is an evidence of the *infinite variety* which exists throughout the universe, and shows us by what apparently simple means this variety is produced. We are thus led to conclude, that among all the systems and worlds dispersed throughout boundless space, there is no one department of creation exactly resembling another. This is likewise exemplified in the boundless variety exhibited in our world, in the animal, vegetable, and mineral kingdoms. 5. The alternations of light and darkness, and the frequent eclipses of the celestial luminaries which happen among the bodies connected with Jupiter, Saturn, and Uranus, so far from being inconveniences and evils, may be considered as blessings and enjoyments; for it is only or chiefly when their inhabitants are deprived of the direct light of the sun, or its reflection from the satellites, that the starry heavens will appear in all their glory; and as the interval in which they are thus deprived of light is short, and as it adds to the variety of the celestial scene, it must be productive of pleasure and enjoyment. 6. The same planets will be seen in the firmaments of the satellites as in those of their primaries; but they will be seldom visible on account of the large portion of reflected light which will be diffused throughout their sky, ex-

cept in those cases when their nocturnal luminaries suffer an occultation or a total eclipse. The bodies more immediately connected with their own system will form the chief objects of their attention and contemplation, and will appear more interesting and magnificent than any phenomena connected with more distant worlds. 7. On all the satellites, and particularly on the rings of Saturn, it will be more difficult to ascertain the true system of the universe than in any other point of the solar system. I have already alluded to the difficulty of determining the true system of the world as observed from the moon; but it will be still more difficult in the case of observers placed on the rings or satellites of Saturn. The numerous bodies which are seen every hour shifting their aspects and positions, the apparent complication of motions which they will exhibit, their phases, eclipses, and rapid diminution of apparent size, combined with the apparent diurnal revolution of the heavens and of all the bodies in their firmament, will require numerous and accurate observations, and powers of intellect superior to those of man, in order to determine with precision their place in the solar system and the true theory of the universe.

CHAPTER IX.

ON THE DOCTRINE OF A PLURALITY OF WORLDS, WITH AN ILLUSTRATION OF SOME OF THE ARGUMENTS BY WHICH IT MAY BE SUPPORTED.

In the preceding descriptions of the facts connected with the bodies which compose the planetary system, and of the celestial scenery displayed in their respective firmaments, I have assumed the position that they are all peopled with intellectual beings. This is a conclusion to which the mind is almost necessarily led, when once it admits the facts which have been ascertained by modern astronomers. It requires, however, a minute knowledge of the whole scenery and circumstances connected with the planetary system before this truth comes home to the understanding with full conviction.

As in the preceding pages I have stated, with some degree of minuteness, the prominent facts connected with all the bodies of the solar system (except comets), so far as they are yet known, the way is now prepared for bringing forward a few arguments founded on these facts, which will require less extensive illustrations than if I had attempted to discuss this topic without the previous descriptions. It may be proper, however, to state, that in this volume I propose to bring forward *only a few* of those arguments or considerations by which the position announced above may be corroborated and supported, leaving the discussion of the remaining arguments to another volume, in which the other portions of the scenery of the heavens will be described. This is rendered almost indispensable on account of the size to which the present volume has already swelled.

SECTION I.

The first argument I shall adduce in support of the doctrine of a plurality of worlds is, that *there are bodies in the planetary system of such* MAGNITUDES as to *afford ample scope for the abodes of myriads of inhabitants.*

This position has been amply illustrated in the preceding parts of this volume, particularly in chapter iii. From the statements contained in chapter vi., it appears that the whole planetary bodies, exclusive of the sun, comprehend an area of more than *seventy-eight thousand millions of square miles,* which is *three hundred and ninety-seven times* the area of our globe; so that the surfaces of all the planets and their satellites are equal, in point of space, to 397 worlds such as ours. But as the greater part of our globe is covered with water, and, consequently, is unfit for the permanent residence of rational beings, and as we have no reason to believe that the other planets have such a proportion of water on their surface, if we compare the habitable parts of the earth with the extent of surface on the planets, we shall find that they contain *one thousand five hundred and ninety-five times* the area of all that portion of our globe which can be inhabited by human beings. If we take into consideration the *solid contents* of these globes, we find that they are more than *two thousand four hundred and eighty times* the bulk of our globe; and the number of inhabitants they would contain, at the rate of England's population, is no less than 21,895.000,000,000, or nearly *two bill-*

ions, which is more than *twenty-seven thousand times* the present population of our globe. In other words, the extent of surface on all the planets, their rings and satellites, in respect of space for population, is equivalent to 27,000 worlds such as ours in its present state.

Now, can we for a moment imagine that the vast extent of surface on such magnificent globes is a scene of barrenness and desolation; where eternal silence and solitude have prevailed, and will for ever prevail; where no sound is heard throughout all their expansive regions; where nothing appears but interminable deserts, diversified with frightful precipices and gloomy caverns; where no vegetable or mineral beauties adorn the landscape; where no trace of rational intelligences is to be found throughout all their wastes and wilds; and where no thanksgivings, nor melody, nor grateful adorations ascend to the Ruler of the skies? To suppose that such is the state of these capacious globes would exhibit a most gloomy and distorted view of the character and attributes of the Creator. It would represent him as exerting his creating power to no purpose; and as acting in a different, and even in an *opposite character*, in different parts of his dominions; as displaying wisdom in one part of his creation, and an opposite attribute in another. For, so far as we are able to penetrate, it appears demonstrable that matter exists chiefly, if not *solely*, for the sake of sensitive and intellectual beings; either to serve the purpose of gratifying the senses, or of affording a medium of thought to the mental faculty, or of exhibiting to the mind a sensible display of the existence and perfections of the supreme Intelligence. And if it serve such purposes in this part of the creation which we occupy, reason says that it must serve similar purposes in other regions of the universe. How incongruous would it be to maintain that matter serves such purposes in our terrestrial sphere, and nowhere else throughout the range of the planetary system? In other words, that it is useful to sensitive existences within the compass of the *one four hundredth part* of that system, but serves no useful or rational purpose in the other three hundred and ninety-nine parts; for the area of the earth, as above stated, is only about the one four hundredth part of the area of all the other planets. Such a conclusion can never be admitted in consistency with those perfections which both natural and revealed religion attribute to the Deity. If matter

was not created merely for itself, but for the enjoyment of a superior nature, then it necessarily follows, that *wherever matter exists, that nobler nature*, whether sensitive or intellectual, *for whose sake it was created, must likewise exist* throughout some portions of its extent. To replenish one comparatively little globe with sensitive and rational inhabitants, and to leave several hundreds empty, desolate, and useless, is the perfect reverse of art and contrivance, and altogether incompatible with the conceptions we ought to form of Him who is "the only wise God," and who is declared to have displayed himself, in all his operations, as "wonderful in counsel and excellent in working."

In accordance with this sentiment, we find the inspired writers, when speaking in the name of Jehovah, admitting the validity of such reasoning. "Thus saith Jehovah that created the heavens; God himself that formed the earth and made it: he hath established it; HE CREATED IT NOT IN VAIN; HE FORMED IT TO BE INHABITED. I am Jehovah, and there is none else."* Here it is plainly and pointedly declared, that to create the earth without the design of its being inhabited would have been a piece of folly inconsistent with the perfections of Him whose intelligence and wisdom are displayed throughout all his works. To have left it empty and useless would have been "to create it in vain." It would neither have contributed to the enjoyment of intellectual beings, nor served as a manifestation of the intelligence, wisdom, and beneficence of its Creator. This passage likewise intimates that it is the ultimate design of Jehovah that this world shall, ere long, be fully peopled with inhabitants, and that its forests and desolate wastes shall, in future ages, be transformed into scenes of beauty and fertility, fitted for being the abodes of renovated moral agents at that period when "the knowledge of the Lord shall cover the earth;" and this extension of population and of cultivation is evidently going forward with rapid progress at the present time in different quarters of the globe. In connexion with this declaration respecting the earth, it is also declared, that the same Almighty Being that arranged the earth for the purpose of replenishing it with inhabitants, likewise "*created the heavens*;" plainly intimating, that as both the fabrics were erected by the same all-wise and

* Isaiah xlv., 18.

omnipotent intelligence, the same wisdom is displayed in both, and that the same grand and beneficent designs are accomplished in the globes which roll in the heavens as well as in the constitution of the earth in which we dwell. If the one was created for *use*, for the enjoyment of rational natures, and as a theatre on which the Divine perfection might be displayed, so was the other. It is added, "I am Jehovah, and there is none else;" implying that there is a *unity* of principle, design, and operation in all his plans and arrangements throughout the universe, however different the means employed, and however varied the effects produced in different parts of his dominions.

Some, however, may be disposed to insinuate that the Deity may have designs in view, in the creation of matter, of which we are altogether ignorant, and that the planets and other bodies in the heavens may display the Divine glory in some way or another, although they be not peopled with inhabitants. It is readily admitted that we are ignorant of many of the purposes of the Deity, of the details of his operations in the distant regions of creation, and of many of the plans and movements of his moral government; and that, through an eternal lapse of ages, we shall always remain in ignorance of some of the works and ways of the Almighty. But there are certain general principles and views with which the Deity evidently intends that all his rational creatures should be acquainted. It was evidently intended that the visible creation should *adumbrate*, as it were, the character of him who produced it; or that it should serve as a mirror, in which his existence and some of his perfections might be clearly perceived. But if the great globes of the universe were destitute of inhabitants, how could the Divine glory be discovered in their structure? How could a confused mass of rubbish and desolation, however vast and extensive, display the intelligence, the wisdom, and the benevolence of its Maker? It might indicate a power surpassing our comprehension, but it would display no other perfection which tends to excite the admiration, the love, and the adoration of rational beings. Yet we are informed in the scriptures that celestial intelligences celebrate the perfections of Jehovah, "because he hath created all things," and because they perceive "his works" to be "GREAT AND MARVELLOUS." They ascribe to him "wisdom, and glory, and honour, and power, and thanksgiving," from the display of his

character which they perceive in his works. But how could they ascribe to him such perfections, if the mightiest of his works were a scene of barrenness and desolation? Wisdom can be attributed only where there appears to be a proportionating of *means* to *ends*; and goodness can have no place where there are no sensitive or rational beings to enjoy the effects of it. It is, therefore, a mere evasion to assert that the Divine glory may be manifested in the celestial globes, although destitute of inhabitants. Every part of the character of God, by which he is rendered amiable and adorable in the eyes of his intelligent offspring, would be obscured and distorted were we for a moment to harbour such a sentiment. For wherein does the Divine glory consist? It chiefly consists in the display of infinite *wisdom*, rectitude, holiness, and unbounded beneficence; and where such attributes are not manifested there cannot be said to be a display of Divine glory. But such attributes could never be traced by man, or by any other order of intelligences, were the planetary bodies and the other orbs of heaven a scene of eternal silence, solitude, and waste; where no percipient being existed to taste the goodness or to adore the perfections of its Creator.

SECTION II.

Argument II. *There is a* GENERAL SIMILARITY *among all the bodies of the Planetary System, which tends to prove that they are intended to subserve the same ultimate designs in the arrangements of the Creator.*

In the elucidation of this argument it will be requisite that a variety of facts, some of which have been noticed in the preceding pages, should be brought under review. We are not to imagine that the planets, considered as habitable worlds, are arranged exactly according to the model of our terrestrial habitation; for the Creator has introduced an infinite variety in every department of his works; and we know from observation that there are certain arrangements connected with those bodies which are very different from those which are found in connexion with our globe. But in all worlds destined for the habitation of intellectual natures we should expect to find some general analogy or resemblance in their prominent features, and in those things which appear essential to the enjoyment of such beings. Were we to attend the

dissection of any animal—a dog, for example—and perceive the heart, the stomach, the liver, the lungs, the veins, arteries, and other parts essential to life and enjoyment, we could scarcely doubt that the same organs, though perhaps somewhat modified, were likewise to be found in a cat, a bullock, or any other quadruped, and that they served the same purposes in all these animals. In like manner, when we find on our globe certain parts and arrangements essentially requisite to its being a habitable world, and when we likewise observe similar contrivances connected with other distant globes, we have every reason to conclude that they are intended to subserve similar designs. In accordance with this principle, I shall now proceed to detail a few contrivances and arrangements in the other planets, which evidently indicate that their grand and ultimate design is to afford enjoyment to sensitive and intellectual natures.

1. *All the planets*, both primary and secondary, *are of a spherical or spheroidal figure* similar to that of the earth. I have already shown (p. 298) that this figure is the most capacious and the best adapted to motion, both annual and diurnal, and that the greatest inconveniences would be produced were any world constructed of an angular figure. The only deviation from this figure is to be found in the rings of Saturn. But these rings are not angular bodies; for even the thin exterior edge of the rings is supposed, from some minute observations, to be curved; and, if so, it prevents the inconveniences which would arise from an angular construction. The flat sides of the rings, too, appear to have no angular elevations or protuberances more than what may be supposed from a gently-waving surface such as that of our globe; and although they are not globular bodies, they are *circular*, with thin edges, and are thus calculated for rapid motion along with the planet; and the flat sides, having no angular projections, appear perfectly adapted for being places of habitation, without any of those inconveniences or catastrophes which might ensue had they approximated to a cubical, prismatic, or pentagonal form. The rings, in short, approximate nearer to the globular figure and its conveniences than any other construction could have done, and show us that, although the Creator proceeds in his operations on some grand general principles, yet he is not limited or confined to one particular figure or construction in arranging the celes-

tial worlds. The planets, then, being all of a globular or circular form, appear completely adapted for being the abodes of living beings.

2. The planets are *solid bodies* similar to the earth. They are not merely a congeries of clouds and vapours formed into a globular shape, but possessed of weight, solidity, or gravity. This is evident from the dark and well-defined shadows which they throw on other bodies, and from the attractive influence they exert throughout the system. Their *figure* is a proof that they possess such qualities ; for their roundness proceeds from an equal pressure of all their parts tending towards the same centre. Nay, astronomers, by the aid of observation and mathematical calculations, can tell what are the relative gravities or weights of the different planets ; what proportion, for instance, the gravitation in Jupiter or Saturn bears to that of our earth, and what influence their attractive power produces on their own satellites, on the motion of comets, and on the smaller and inferior planets. In consequence of this solidity and attractive power, all things connected with their surfaces are preserved in security and prevented from flying off to the distant regions of space ; for it is this power, variously modified and directed, that preserves the material universe, and all the orders of beings connected with it, in compact order and harmony, without the influence of which all things in heaven and earth would soon be reduced to a universal chaos. In this respect, then, as well as in the former, the planets are fitted for the support of intellectual beings, furnished with material organs.

3. All the planets have an *annual revolution* round the sun. This revolution, in the case of the earth, combined with the inclination of its axis to the plane of its orbit, produces the variety of seasons ; and although we are not to suppose that all the planets have seasons similar to ours, or that the heats of summer and the cold of winter are experienced in other worlds (see p. 121, 122), yet there is a certain variety of scene produced by this revolution in all the planets, particularly in those which have their axes of rotation inclined more or less to the plane of their orbits. This variety of scene will be particularly experienced on Saturn and on the surface of its rings ; for in the course of one half of the annual revolution the sun will shine on certain parts of these bodies, and during the other half they will be deprived of his direct

influence. The annual revolutions of the planets, therefore, appear expedient, in order to produce an agreeable interchange and variety of scene, for the purpose of gratifying their inhabitants. The periods of these revolutions, too, are adjusted with the utmost exactness. The planets perform their circuits without deviating in the least from the paths prescribed, and finish their revolutions exactly in the appointed time, so as not to vary the space of a minute in the course of centuries. Now, were these bodies merely extensive regions of uncultivated deserts, or were they placed in the vault of heaven merely that a few terrestrial astronomers might peep at them occasionally through their glasses, it is not at all likely that so much care and accuracy would have been displayed in marking out their orbits and adjusting their motions and revolutions.

4. The planets perform *a diurnal rotation* round their axes. This has been ascertained in reference to Venus, Mars, Jupiter, and Saturn, and we may justly conclude, from analogy, that the same is the case in respect to all the other planets. Wherever spots have been discovered on the surface of any planet, it has uniformly been found to have a diurnal rotation. But where no spots or prominences have been observed, it is obvious that no such motion, though it really exist, can be detected. No spots have been observed on the planet Mercury, on account of its smallness and its proximity to the sun; nor on the planet Uranus, on account of its very great distance from the earth; but there can be no doubt whatever that they have a diurnal motion as well as the other planets By this motion every part of their surface is turned in succession towards the sun, and the alternate changes of day and night are produced. Were no such motion existing, one half of these globes would be entirely uninhabitable, for the enlivening rays of the sun would never cheer its desolate regions, and the other half might be dazzled or parched with heat under the perpetual effulgence of the solar beams. Besides, the continuance of a perpetual day, and the illumination of the sky by an uninterrupted efflux of solar light, would prevent the distant regions of creation from being seen and contemplated, so that no body, except the sun himself, and the planet on which the spectator stood, would be known to exist in the universe. But it appears to have been the intention of the Creator not only to cheer the planets by the

invigorating influence of the sun, but likewise to open to the view of their inhabitants a prospect into the regions of distant worlds, that they may behold a display of his wisdom and omnipotence, and of the magnificence of his empire; and this object has been completely effected in every part of the system by impressing upon the planets a motion of rotation, so that there is no body within the range of the solar influence that does not, at one period or another, enjoy this advantage.

The idea of night among the celestial bodies ought not to be associated with gloom, and darkness, and deprivation of comforts. In our world this is frequently the case. A cloudy atmosphere, combined with the fury of raging winds, hurricanes, and the appalling thunder-storm, frequently renders our nights a scene of gloom and terror, especially to the benighted traveller and the mariner in the midst of the ocean. But such gloomy and terrific scenes would never have taken place had our globe and its inhabitants remained in that state of order and perfection in which they were originally created; and, therefore, we are to consider such physical evils as connected with the *moral state* of the present inhabitants of the earth. But even here, amid the gloom and darkness which frequently surround us, *night* not unfrequently opens to view a scene of incomparable splendour and magnificence; a scene which, were it confined to one quarter of the globe, millions of spectators would be eager to travel thousands of miles in order to behold it. In a clear and serene sky, night unfolds to us the firmament bespangled with thousands of stars, twinkling from regions immensely distant, and the planets revolving in their different circuits, all apparently moving around us in silent grandeur. When the moon appears amid the host of stars, the scene is diversified and enlivened. Poets and philosophers in all ages have been charmed and captivated with the mild radiance of a moonlight scene, which partly unveils even the distant landscape, and throws a soft lustre and solemnity both on earth and sky altogether different from their aspect under the meridian sun. But we have already shown (chapter viii.) that the splendour of the heavens during night in some of the other planets is far more magnificent and diversified than what is exhibited in our firmament. The nocturnal scenes in the heavens of Jupiter, Saturn, Uranus, and their rings and satellites, in point of sublimity and variety,

exceed every conception we can now form of celestial grandeur and magnificence; and, therefore, it is highly probable that in those regions the scenes of night will be far more interesting and sublime, and will afford objects of contemplation more attractive and gratifying than all the splendours of their noonday. In this rotation of the planetary orbs there is a striking display both of wisdom and goodness, in causing a means so apparently simple to be productive of so rich a variety of sublime and beneficent effects; and this circumstance of itself affords a strong presumptive evidence that every globe in the universe which has such a rotation is either a world peopled with inhabitants, or connected with a system of habitable worlds; for, without such a motion, the one half, at least, of every globe would be unfit for the residence of organized intelligences. It is not improbable that most, if not all the globes of the universe have a diurnal rotation impressed upon them. We find that even the globe of the sun has a motion of this kind, which it performs in the course of twenty-five days; and the phenomena of variable stars have induced some astronomers to conclude that their alternate increase and diminution of lustre is owing to a motion of rotation around their axes.

5. All the planets and their satellites are *opaque bodies*, which derive their lustre from the sun. That Venus and Mercury are opaque globes, which have no light in themselves, is evident from their appearing sometimes with a gibbous phase, and at other times like a crescent or a half moon; and particularly from their having been seen moving across the disk of the sun like round black spots. Mars, being a superior planet, can never appear like a crescent or a half moon; but at the time of its quadrature with the sun it assumes a gibbous phase, somewhat approaching to that of a half moon, which likewise proves that it is an opaque globe. Jupiter and Saturn must always appear round, on account of their great distance from the earth; but that Jupiter is opaque appears from the dark shadows of his satellites moving across his disk when they interpose between him and the sun; and that Saturn is likewise a dark body of itself appears from the shadow of the rings upon its disk. That the moon is an opaque body has been already shown (p. 252), and it is obvious to almost every observer; and that the satellites of Jupiter and Saturn are opaque appears from their eclipses, and the shadows they

project on their respective planets. In this respect both the primary and the secondary planets are bodies analogous to the earth, which is likewise opaque, and derives its light either directly from the sun or by reflection from the moon, except the few feeble rays which proceed from the stars. It forms, therefore, a presumptive argument that all these bodies have a similar destination; for we cannot conceive any other globe so well fitted for the habitation of rational beings as that which is illuminated by light proceeding from another body. An inherent splendour on the surface of any globe would dazzle the eyes with its brilliancy, and could never produce such a beautiful diversity of form, shade, and colouring as appears on the landscapes of the earth, by means of the reflections of the solar rays. And, therefore, if the sun be inhabited, it can only be its dark central nucleus, and not the exterior surface of its luminous atmosphere.

6. The bodies belonging to the planetary system *are all connected together by one common principle or law*, namely, the law of gravitation. They are all subject to the attractive influence of the great central luminary; they revolve around it in conformity to the general law, that the squares of their periodical times are proportional to the cubes of their distances; they describe equal areas in equal times; their orbits are elliptical; they are acted upon by centripetal and centrifugal forces; and they all produce an attractive influence on each other, in proportion to their distances and the quantity of matter they contain. Being thus assimilated and combined into one harmonious system, the presumption is, that, however different in point of distance, magnitude, and density, they are all intended to accomplish the same grand and beneficent design, namely, to serve as the abodes of living beings, and to promote the enjoyment of intellectual natures.

Since the planets, then, are all similar to one another in their spherical or spheroidal figures; in their being solid and opaque globes; in their annual and diurnal revolutions; and in being acted upon by the same laws of motion; and since these circumstances are all requisite to the comfort and enjoyment of living beings, it is a natural and reasonable conclusion that their ultimate destination is the same, and that they are all replenished with inhabitants. This earth on which we dwell is one of the bodies possessed of the qualities and arrangements to which we allude; and we know that its

chief and ultimate design is to support a multitude of sensitive and intellectual beings, and to afford them both physical and mental enjoyment. Had not this been its principal destination, we are assured, on the authority of Divine revelation, that "*it would have been created in vain.*" We must therefore conclude that all the other globes in our system were destined to a similar end, unless we can suppose it to be consistent with the perfections of Deity that they were created for no purpose.

SECTION III.

Argument III. *In the bodies which constitute the solar system, there are* SPECIAL ARRANGEMENTS *which indicate their* ADAPTATION *to the enjoyments of sensitive and intelligent beings; and which prove that this was the ultimate design of their creation.*

This argument is somewhat similar to the former; but it may be considered separately, in order to prevent an accumulation of too many particulars under one head.

1. The surfaces of the planets *are diversified with hills and valleys, and a variety of mountain scenery.* This is particularly observable in the moon, whose surface is diversified with an immense variety of elevations and depressions, though in a form and arrangement very different from ours (see p. 255–262). It cannot be ascertained by direct observation that there are mountains on the surfaces of Jupiter, Saturn, or Uranus, by reason of their great distances from the earth. But that they are rough or uneven globes appears from their reflecting the light to us from every part of their surfaces, and from the spots and differences of shade and colour which are sometimes distinguishable on their disks. For if the surfaces of the planets were perfectly smooth and polished, they could not reflect the light in every direction; the reflected image of the sun would be too small to strike our eyes, and they would consequently be invisible. (See p. 252.) Indications of mountains, however, have been seen on some of the other planets, particularly on Venus. Spots have been observed on this planet on different occasions, and the boundary between its dark and enlightened hemisphere has appeared jagged or uneven, a clear proof that its surface is diversified with mountains and vales. One of these mountains was cal-

culated by Schroeter to be nearly eleven, and another twenty-two miles in perpendicular elevation; and there can be but little doubt that such inequalities are to be found on the surfaces of all the planets and their satellites, although they are not distinctly visible to us on account of their distance.

The existence of *mountains* on the planets is therefore a proof, or, at least, a strong presumptive evidence, that they are habitable worlds; for a perfectly smooth globe could present no great variety of objects or picturesque scenery, such as we behold in our world, and would doubtless be attended with many inconveniences. The view from any point of such a globe would be dull and monotonous, like the expanse of the ocean, or like the deserts of Zahara or Arabia. It is the beautiful variety of hills and dales, mountains and plains, and their diversity of shadows and aspects, that render the landscapes of the earth interesting and delightful to the painter, the poet, the man of taste, and the traveller. Who would ever desire to visit distant countries, or even distant worlds, if they consisted merely of level plains, without any variety, of several thousands of miles in extent? The mountains add both to the sublimity and the beauty of the surface of our globe; and from the summits of lofty ranges the most enchanting prospects are frequently enjoyed of the rivers and lakes, the hills and vales, which diversify the plains below. But besides the beauty and variety which the diversity of surface produces, mountains are of essential *use* in the economy of our globe. They afford many of the most delightful and salubrious places for the habitations of man; they arrest the progress of stormy winds; they serve for the nourishment of animals, and the production of an infinite variety of herbs and trees; they are the depositories of stones, metals, minerals, and fossils of every description, so necessary for the use of man; and they are the portions of the globe where fountains have their rise, and whence rivers are conveyed to enliven and fertilize the plains. For, if the earth were divested of its mountains, and every part of its surface a dead level, there could be no running streams or conveyance for the waters, and they would either stagnate in large masses or overflow immense tracts of land. Hence it has been arranged by the wisdom of Providence that mountains should exist over all the globe, and that every country should enjoy the numerous benefits which such an arrangement is fitted to produce.

As mountains, then, are part of the arrangements of other globes in the solar system, and as they are essentially requisite in such a world as ours, they may serve similar and even more important purposes in other worlds. In some of the planets they appear to be more elevated and of greater dimensions than on the earth. Although the moon is much less in size than our globe, yet some of its mountains are reckoned to be five miles in perpendicular height. Some of the mountains on Venus are estimated to be four times higher than even this elevation. We may easily conceive what an extensive and magnificent prospect would be presented from the top of such sublime elevations, and what a diversity of objects would be presented to the eye from one point of view. Nor need we imagine there will be any great difficulty in ascending such lofty eminences; for the inhabitants of such worlds may be furnished with bodies different from those of the human race, and endowed with locomotive powers far superior to ours. If, therefore, the planets were found to be perfectly smooth globes, without any elevations or depressions, we should lose one argument in support of their being designed for the abodes of rational beings; but having the characteristic now stated, when taken into consideration with other arguments, it corroborates the idea of their being habitable worlds.

2. The planets, in all probability, are environed with *atmospheres*. It appears pretty certain that the moon is surrounded with such an appendage (see p. 267–269). The planet Mars is admitted by all astronomers to be environed with a pretty dense atmosphere, which is the cause of its ruddy appearance (see p. 136, 137); and indications of an atmosphere have been observed on Venus and some of the other planets. To our world an atmosphere is a most essential appendage. Without its agency our globe would be unfit for being the residence of living beings constituted as they now are; and were it detached from the earth, all the orders of animated nature, and even the vegetable tribes, would soon cease to exist. Atmospheres somewhat analogous to ours may likewise be necessary in other worlds. But we have no reason to conclude that they are exactly similar to ours. While our atmosphere consists of a compound of several gaseous substances, theirs may be formed of a pure homogeneous ethereal fluid, possessed of very different properties.

While ours is impregnated with dense vapours, and interspersed with numerous strata of thick clouds, the atmospheres of some of the other planets may be free of every heterogeneous substance, and perfectly pure and transparent. Their reflective and refractive powers, and other qualities, may likewise be different from those of the atmosphere which surrounds the earth. Hence the folly of denying the existence of an atmosphere round the moon or any other planet, because a fixed star or any other orb is not rendered dim or distorted when it approaches its margin. For if its atmosphere be either of small dimensions, or perfectly pure and transparent, or of a different refractive power from ours, such a phenomenon cannot be expected. We have no more reason to expect that the atmospheres of other planets should be similar to ours, than that these bodies should be of the same size, have the same diversity of objects on their surface, or be accompanied with the same number of moons.

It is not likely that our atmosphere is precisely in the same state as at the first creation. Its invigorating powers had then an influence sufficient to prolong human existence to a period of a thousand years; but, since the change it underwent at the deluge, the period of human life has dwindled down to little more than "threescore years and ten." The present constitution of our atmosphere, therefore, ought not to be considered as a model by which to judge of the nature and properties of the atmospheres of other worlds. Their atmospheres may be so pure and transparent as to enable their inhabitants to penetrate much farther into space than we can do, and to present to them the heavenly bodies with more brilliancy and lustre; and the properties with which they are endowed may be fitted to preserve their corporeal organs in undecaying vigour, and to raise their spirits to the highest pitch of ecstasy, similar to some of the effects produced on our frame by inhaling that gaseous fluid called the *nitrous oxyde*. There is only one planet whose atmosphere appears to partake of the impurity and density of that of the earth, and that is the planet Mars; and several other circumstances tend to show that it bears too near a resemblance to our globe. In this respect, then, it gives indication of being a habitable world; but several of the other planets may be abodes of greater happiness and splendour, although no traces of such an appendage can be distinguished by our telescopes. And

this very circumstance, that their atmospheres are invisible, should lead us to conclude that they are purer and more transparent than ours, and that the moral and physical condition of their inhabitants is probably superior to what is enjoyed upon earth.

3. There is provision made *for the distribution of light, and heat, and colour* among all the planets and their satellites. On every one of these bodies the sun diffuses a radiance, and, in order that no portion of their surfaces may be deprived of this influence, they appear all to have a motion round their axes. *Light* is an essential requisite to every world, and *colour* is almost equally indispensable. Without colour we should be unable to perceive the forms, proportions, and aspects of the objects which surround us; we could not distinguish one object from another; all the beauties, varieties, and sublimities of nature would be annihilated, and we should remain destitute of the noblest entertainments of vision. It is colour which enlivens every scene of nature, which adds a charm to every landscape, and gives an air of beauty and magnificence to the spacious vault of heaven. Now colour exists in the solar rays, without which, or some similar radiance, every object is either invisible or wears a uniform aspect. On whatever objects these rays fall, colour is produced; they have the same properties in every part of the system as on our globe, and, therefore, must produce colours of various hues on the objects connected with the remotest planets, according to the nature of the substances on which they fall. Light and colour, then, being essential to every globe intended for the habitation of living beings, abundant provision has been made for diffusing their benign influence through every part of the planetary system. Heat is likewise an agent which appears necessary to every world; and it is, doubtless, distributed in due proportions throughout the system, according to the nature of the substances of which the planets are composed, and the constitution of their inhabitants. But light, and colour, and heat are agencies which can only have an ultimate respect to sensitive and intellectual beings; and, therefore, where no such beings exist or are intended to exist, no such provision would be made by a wise and intelligent agent. Such care as appears to have been taken for the communication of the agencies of light, heat, and colour, would never have been exercised for the sake of rocks and deserts,

and scenes of sterility and desolation. The existence of *light*, with all the enchanting effects it produces, necessarily supposes the existence of *eyes*, in order to enjoy its beneficial influence; and, therefore, organized beings, endowed with *visual organs*, must exist in all those regions where contrivances have been adapted for its regular and universal diffusion; otherwise the universe might have remained a scene of eternal darkness.

4. The principal primary planets *are provided with secondary planets or moons*, to afford them light in the absence of the sun, as well as to accomplish other important purposes. The three largest planets of the system are accommodated with no fewer than *seventeen* of those nocturnal luminaries, and probably with several more which lie beyond the reach of our telescopes. Our earth has one; and it is not improbable that both Mars and Venus are attended by at least one satellite. These attendants appear to increase in number in proportion to the distance of the primary planet from the sun. Jupiter has four such attendants; Saturn seven; six have been discovered around Uranus; but the great difficulty of perceiving them, at the immense distance at which we are placed, leads to the almost certain conclusion that several more exist which have not yet been detected. While these satellites revolve round their respective planets, and diffuse a mild radiance on their surfaces in the absence of the sun, they also serve the same purposes to one another; and their primaries, at the same time, serve the purpose of large resplendent moons to every one of their satellites, besides presenting a diversified and magnificent scene in their nocturnal sky. No satellite has yet been discovered attending the planet Mercury, nor is it probable that any such body exists. But we have already shown (p. 331–334) that Venus and the earth serve the purposes of satellites to this planet, Venus sometimes appearing six times as large, and the earth two or three times as large as Venus does to us at the period of its greatest brilliancy; so that the nights of Mercury are cheered with a considerable degree of illumination. Here, then, we perceive an *evident design* in such arrangements, which can have no other ultimate object in view than the comfort and gratification of intelligent beings. For a retinue of moons, revolving around their primary planets at regular distances and in fixed periods of time, would serve no useful purpose in throwing a faint

light on immense deserts, where no sensitive beings, furnished with visual organs, were placed to enjoy its benefits; nor, if this were the case, is it supposable that so much skill and accuracy would have been displayed in arranging their distances and their periodical revolutions, which is accomplished with all the accuracy and precision which are displayed in the other departments of the system of nature.

The *small density* of the larger and more remote planets, and *the diminution of the weight of bodies on their surfaces* on this account, and by their *rapid rotation* on their axes, appear to be instances of design which have a respect to sentient beings. The density of Jupiter is little more than that of water, and that of Saturn about the density of cork. Were these planets as dense as the planet Mercury, or had they even the density of the earth, organized beings like man would be unable to traverse their surfaces. If the density of Jupiter, for example, were as great as that of the earth, the weight of bodies on its surface would be eleven times greater than with us; so that a man weighing 160 pounds on the earth would be pressed down on the surface of Jupiter with a force equal to one thousand seven hundred and sixty pounds. But the gravity of bodies on the surface of this planet is only about twice as great as on the surface of the earth; and *this gravitating power is diminished by its rapid rotation on its axis.* For the centrifugal force which diminishes the weight of bodies is *sixty-six* times greater on Jupiter than on the earth, and will relieve the inhabitants of one eighth part of their weight, which they would otherwise feel if there were no rotation; so that a body weighing 128 pounds if the planet stood still, would weigh only 112 pounds at its present rate of rotation, which will afford a sensible relief and diminution of weight (see p. 168, Art. *Jupiter*). The same may be said, with some slight modifications, in relation to Saturn. There must, therefore, have been a *design*, or a wise and prospective contrivance in such arrangements, to suit the exigences and to promote the comfort of organized intelligences; otherwise, had Jupiter and Saturn been as much denser than the earth as they are lighter, every body would have been riveted to their surfaces with a force which beings like man could never have overcome; and moving beings with such organical parts as those of men would have had to drag along with them a weight of eight or ten thousand pounds.

In the preceding statements I have endeavoured to show that there is a *general similarity* among all the bodies of the planetary system, and that there are *special arrangements* which indicate their *adaption* to the enjoyment of sensitive and intellectual beings. Let us now consider more particularly the force of the argument derived from such considerations:

That the Divine Being has an *end* in view in all his arrangements, and that this end is in complete correspondence with his infinite wisdom and goodness, and the other perfections of his nature, is a position which every rational Theist will readily admit. That some of the prominent designs or general ends which the Deity intended to accomplish may be traced in various departments of his works, is likewise a position which few or none will deny. That design may be inferred from its effects, is a principle which mankind generally recognise in their investigations of the operations both of nature and of art. That man would justly be accused of insanity who, after inspecting the machinery of a well-constructed clock, and perceiving that it answered the purpose of pointing out the divisions of time by hours, minutes, and seconds with the utmost accuracy, should *deny* that its various parts were formed and arranged for the very purpose which the machine so exactly fulfils; at least, that the pointing out of the hours and minutes was one of the main and leading objects which the artist had in view in its construction. It is a law of our nature which we cannot resist, that from the effect the design may be inferred; and that, wherever art or contrivance appears exactly adapted to accomplish a certain end, that end was intended to be accomplished. We cannot doubt for a moment of the final causes of a variety of objects and contrivances which present themselves to view in the world we inhabit. We cannot err in concluding, for example, that the ears, legs, and wings of animals were made for the purpose of hearing, walking, and flying. On the same principle we are led to conclude, that as animals are formed with mouths, teeth, and stomachs to masticate and digest their food, so vegetables and other organized bodies were formed for the purpose of affording that nourishment which the animal requires. No

one will take upon him to deny that the eye was intended for the purpose of vision. The coats and humours of which it is composed, and the muscles which move it in every direction, in their size, shape, connexion, and positions, are so admirably adapted to this end, and the transparency of the *cornea*, and the *humours*, the opacity of the *uvea*, and the semi-opacity and concavity of the *retina*, are so necessary to transmit and refract the rays of light in order to distinct vision, that it appears as evident it was designed for this purpose, as that telescopes were constructed to discover the colours, shapes, and motions of distant objects. And as the eye was constructed of a number of nice and delicate parts for the purpose of vision, so light was formed for the purpose of acting upon it and producing the intended effect, without the agency of which vision could not be produced. The one is exactly adapted to the other; for no other substance but light can affect the eye so as to produce vision, and no other organ of sensation is susceptible of the impressions of light, so as to convey a perception of any visible object. In all such cases, the adaption of one contrivance to another, and the intention of the Contriver, are quite apparent

It is true, indeed, that we cannot pretend to explore *all the ends or designs* which God may have had in view in the formation of any one object or department of the universe. For an eternal and omniscient Being, whose wisdom is unsearchable, and whose eye penetrates through all the regions of immensity, may have subordinate designs to accomplish, which surpass the limited faculties of man, or even of angels, to comprehend. But to investigate and to perceive *some* of the main and leading ends which were designed in the arrangement of certain parts of the universe, is so far from being presumptuous and unattainable, that it would be blindness and folly in a rational creature not to discover them; particularly in such instances as those to which we have now alluded. For it appears to be the intention of the Deity, in displaying his works to intelligent minds, that these works shall exhibit a manifestation of his attributes, and particularly of his wisdom, goodness, and intelligence; and he has endowed them with faculties adequate to enable them to perceive some traces of his footsteps and of the plan of his operations. But while he permits us to perceive some of the grand lineaments of his designs, there may be numberless minute and subordinate ends

which lie beyond the sphere of our investigations. Were a peasant brought into the observatory of an astronomer, and shown an instrument calculated to point out the sun's place in the ecliptic, its declination and right ascension, the day of the month, &c., and particularly the *hour* of the day, it would be presumptuous in such a person to pretend to ascertain *all* the intentions of the artist, or all the uses for which such a machine was constructed; but when he beheld the ordinary marks of a sundial, and the shadow of the gnomon accurately pointing to the hour, he could not fail at once to perceive that this was *one* principal end which the contriver had in view. In like manner, while we evidently perceive that one principal design of the creation of the sun was to enlighten the earth and other bodies which move around it, it also serves several subordinate purposes. It directs the course of winds, promotes evaporation and the growth of vegetables; it retains the planets in their orbits; it kindles combustible substances by means of convex glasses and concave mirrors; it enables us to measure time by means of dials; it directs the geographer to determine the elevation of the pole and the latitude of places; it guides the navigator in his course through the ocean, and even its eclipses serve many useful purposes, both in chronology and astronomy; and it may serve similar or very different purposes, with which we are unacquainted, among the inhabitants of other worlds. All these purposes, and many more of which we are ignorant, may have entered into the designs of the almighty Creator, although, in the first instance, we might have been unable to discover or appreciate them. As "the works of the Lord are great," so they must "be sought out," or diligently investigated, in order that we may clearly perceive the manifold designs of infinite wisdom.

Let us now apply these principles to the subject more immediately before us. We have seen that, in the distant bodies of our system, there are special contrivances and arrangements, all calculated to promote the enjoyment of myriads of intelligent agents. We have presented before us a most august and astonishing assemblage of *means;* and if the Contriver of the universe is possessed of wisdom, there must be an *end* proportionate to the utility and grandeur of the means provided. Arrangements nearly similar, but much inferior in point of extent and magnificence, have been made in relation to the globe on which we live. We know the final cause,

or, at least, one of the principal designs for which it was created, namely, to support sensitive and intellectual beings, and to contribute to their enjoyment. If, then, the Creator acts on the same principles—in other words, if he displays the same intelligence—in other regions of the universe as he does in our world, we must admit that the planetary globes are furnished with rational inhabitants. There is one essential attribute which enters into all our conceptions of the Divine Being, namely, *that he is possessed of infinite wisdom.* This perfection of his nature is displayed in all the general arrangements he has made in this lower world, where we find one part nicely adapted to another, and everything so balanced and arranged as to promote the comfort of sentient beings. In consequence of his being possessed of this perfection, he must be considered, in *all* his operations throughout the immensity of space, as proportionating the means to the end, and selecting the best means possible for the accomplishment of any design; for in such contrivances and operations true wisdom consists.

But now let us suppose for a moment that the vast regions on the surfaces of the planets are only immense and frightful deserts, devoid of inhabitants; *wherein does the wisdom of the Creator appear on this supposition?* For what purpose serves the grand apparatus of rings and moons for adorning their sky and reflecting light on their hemispheres? Why are they made to perform annual and diurnal revolutions, and not fixed in the same points of infinite space? Why are the larger and remoter planets furnished with more moons than those which are nearer the source of light? Why are their firmaments diversified with so many splendid and magnificent objects? Why is their surface arranged into mountains and vales? Why has so much contrivance been displayed in devising means for the illumination of every portion of their surfaces, and diffusing over them a variety of colours? The answer to such questions would, then, be, to illuminate an immense number of dreary wastes, and to produce days and nights, and a variety of seasons, for the sole benefit of interminable deserts, or, at most, of mountains of marble or rocks of diamonds; to afford them light enough to see to keep their orbits, lest they might miss their way in the pathless spaces through which they move! Is such an apparatus requisite for such a purpose? *Would this be an end worthy*

of INFINITE WISDOM? Would it at all correspond with the dignity and grandeur of the means employed? Would it comport with the boundless intelligence of Him "who formed the earth by his wisdom, and stretched out the heavens by his *understanding?*" To maintain such a position would be to *distort* the Divine character, and to undermine all the conceptions we ought to form of the Deity, as wise, amiable, and adorable, and as "great in counsel and mighty in operation." If we beheld an artist exerting his whole energies, and spending his whole life in constructing a large complex machine which produced merely a successive revolution of wheels and pinions, without any useful end whatever in view, however much we might extol the ingenuity displayed in some parts of the machine, we could not help viewing him as a fool or a maniac in bestowing so much labour and expense to no purpose. For it is the *end* or design intended which leads us to infer the wisdom of the artist in the means employed. And shall we consider the ALL-WISE AND ADORABLE CREATOR OF THE UNIVERSE as acting in a similar manner? The thought would be impious, blasphemous, and absurd. It is only when we recognise the Almighty as displaying infinite wisdom in all his arrangements throughout creation, and boundless beneficence in diffusing happiness among countless ranks of intelligent existence, that we perceive him to be worthy of our admiration and gratitude, and of our highest praises and adorations. We are, therefore, irresistibly led to the conclusion, that the planets are the abodes of intelligent beings since every requisite arrangement has been made for their enjoyment. This is a conclusion which is not merely probable, but absolutely certain; for the opposite opinion would rob the Deity of the most distinguishing attribute of his nature, by virtually denying him the perfection of infinite wisdom and intelligence.

SECTION IV.

Argument IV. The scenery of the heavens, as viewed from the surfaces of the larger planets and their satellites, forms a presumptive proof that both the planets and their moons are inhabited by *intellectual* beings.

In the preceding chapter I have described at some length the celestial phenomena of the planets, both primary and secondary. From these descriptions it appears that the most

glorious and magnificent scenes are displayed in the firmaments of the remoter planets, and particularly in those of their satellites. Even the firmament of the moon is more striking and sublime than ours. But in the firmaments of some of the satellites of Jupiter and Saturn there are celestial scenes peculiarly grand and splendid, surpassing everything which the imagination can well represent, and these scenes diversified almost every hour. What should we think of a globe appearing in our nocturnal sky 1300 times larger than the apparent size of the moon, and every hour assuming a different aspect? of five or six bodies twenty or thirty times larger than our moon appears, all in rapid motion, and continually changing their phases and their apparent magnitudes? What should we think of a globe filling the twentieth part of the sky, and surrounded with immense rings, in rapid motion, diffusing a radiance over the whole heavens? When Jupiter rises to his satellites, and especially when Saturn and his rings rise to his nearest moons, a whole quarter of the heavens will appear in one blaze of light. At other times, when the sun is eclipsed, or when the dark sides of these globes are turned to the spectator, the *starry* firmament will open a new scene of wonders, and planets and comets be occasionally beheld in their courses through the distant regions of space.

The sublime and magnificent scenes displayed in those regions; the diversified objects presented to view; the incessant changes in their phases and aspects; the rapidity of their apparent motions; and the difficulty of determining the *real* motions and relative positions of the bodies in the firmament, and the true system of the world, lead us to the conclusion that the globes to which we allude are replenished, not merely with sensitive, but with *intellectual* beings. For such sublime and interesting scenes cannot affect inanimate matter, nor even mere sentient beings such as exist in our world; and we cannot suppose that the Creator would form such magnificent arrangements to be beheld and studied by *no rational beings* capable of appreciating their grandeur and feeling delight in their contemplation. If creation was intended as a display of the perfections and grandeur of the Divine Being, there must exist intelligent minds to whom such a display is exhibited; otherwise the material universe cannot answer this end, and might, so far as such a design

is concerned, have remained for ever shut up in the recesses of the Eternal Mind. Such scenes could not have been intended merely for the instruction or gratification of the inhabitants of the earth. For no one of its population has yet beheld them from that point of view in which their grandeur is displayed, and not one out of a hundred thousand yet knows that such objects exist. We are, therefore, irresistibly led to the conclusion that intelligent minds exist in the regions of Jupiter, Saturn, and Uranus, for whose pleasure and gratification these sublime scenes were created and arranged. Those minds, too, in all probability, are endowed with faculties superior in intellectual energy and acumen to those of the inhabitants of our globe. For the rapidity and complexity of the motions presented in the firmament of some of the satellites of Jupiter and Saturn, the variety of objects exhibited to view, and the frequent and rapid changes of their phases and apparent magnitudes, are such as to require the exertion of intellectual faculties more powerful and energetic than ours in order to determine the real motions and positions of the globes around them, and to ascertain the order of the planetary system of which they form a part. And it is likewise probable that their organs of vision are more acute and penetrating than those of men ; otherwise they will never be able to discover either the earth, Mars, Mercury, or Venus, and, consequently, may suppose that such bodies have no existence

SECTION V.

Argument V. The doctrine of a plurality of worlds may be argued from the consideration that, in the world we inhabit, *every part of nature is destined to the support of animated beings.*

There is, doubtless, a certain degree of pleasure in contemplating the material world, and surveying the various forms into which matter has been wrought and arranged, particularly in the admirable structure and movements of systems of bodies such as those which compose the planetary system. But there is something still more interesting and wonderful presented to the mind when we contemplate the worlds of life. The material world is only, as it were, the shell of the universe ; the mere *substratum* of thought and sensation ; living beings are its inhabitants, for whose sake alone matter is valuable, and for whose enjoyment it appears

to have been created. In the organization of animated existences, in the various parts of which they are composed, in the adaptation of one part or organ to another, in their different functions, and the multifarious movements of which they are susceptible, without taking into consideration the soul that animates them, there is a display of the most admirable mechanism and the nicest contrivance, which is not to be found in earth or stones, in rocks of diamonds, or even in the figure of a planet and its motion round the sun.

Hence we find that the world in which we live teems with animated existence. Man is the principal inhabitant, for whose use and accommodation, chiefly, the terraqueous globe was formed and arranged. Had not the Creator intended to place upon its surface beings endowed with rational faculties, capable of enjoying happiness and recognising the perfections of its author, it is not probable that it would have been created. "God made man in his own image," and "gave him dominion over the fish of the sea, over the fowls of the air, and over every living thing that moveth upon the earth." After the light was formed, the bed of the ocean prepared, and the waters separated from the dry land; after luminaries were placed in the firmament, and plants and animals of all kinds brought into existence, the world appeared so magnificently adorned that it might have been thought perfect and complete. But all nature was yet destitute of sentiment and gratitude; there were no beings capable of recognising the Power that formed them, or of praising the Author of their varied enjoyments. The world was still in a state of imperfection, till an intelligence was formed capable of appreciating the perfections of the Creator, of contemplating his works, and of offering to him a tribute of grateful adoration. Therefore "God created man in his own image," as the masterpiece of creation, the visible representative of his Maker, and the subordinate ruler of this lower world.

But although this globe was created chiefly for the residence of man, it was not destined *solely* for his enjoyment. It is impossible for him to occupy the *whole* of its surface, or of the appendages with which it is connected. There are extensive marshes, impenetrable forests, deep caverns, and the more elevated parts of lofty mountains, where human feet have never trod. There is a vast body of water which covers more than two thirds of the surface of the globe, and the greater

part of the atmosphere which surrounds the earth, which men cannot occupy as permanent abodes. Yet these regions of our world are not left destitute of inhabitants. Numerous tribes of animals range through the uncultivated deserts, and find ample accommodation suited to their nature, in rocks and mountains, in dens and caves of the earth. The regions of the air are filled with winged creatures of every kind, from the ostrich and the eagle to the numerous tribes of flying insects almost invisible to the unassisted eye. The ocean teems with myriads of inhabitants which no man can number, of every form and size, from the mighty whale to the numerous tribes of *Medusæ*, of which several thousands of *billions* are contained in a cubical mile of water. Every sea, lake, and river is peopled with inhabitants; every mountain and marsh, every wilderness and wood, is plentifully stocked with birds, and beasts, and numerous species of insects, all of which find ample accommodation, and everything necessary for their comfort and subsistence. In short, every part of matter appears to be peopled; almost every green leaf and every particle of dust has its peculiar inhabitants. Not only are the larger parts of nature occupied with living beings, but even the most minute portions of matter teem with animated existence. Every plant and shrub, and almost every drop of water, contains its respective inhabitants. Their number, in some instances, is so great, and their minuteness so astonishing, that thousands of them are contained within a space not larger than a grain of sand. In some small pools covered with a greenish scum, of only a few yards in extent, there are more living creatures than there are human beings on the surface of the whole earth.

Multitudes of animated beings are found in situations and circumstances where we should never have expected to perceive the principle of life. The juices of animals and plants, corrupted matter, excrements, smoke, dry wood, the bark and roots of trees, the bodies of other animals, and even their entrails, the dunghill, and the dirty puddle, the itch, and other disorders which are attended with blotches and pimples, and even the hardest stones and rocks, serve to lodge, and in some measure to feed, numerous tribes of living beings. The *number* of such creatures exceeds all human calculation and conception. There may be reckoned far more than a hundred thousand species of animated beings, many of these species

containing individuals to the amount of several hundreds of times the number of the human inhabitants of our globe. It is supposed by some that the tremulous motion observed in the air during summer may be produced by millions of insects swarming in the atmosphere ; and it has been found that the light which is seen on the surface of the ocean during the nights of summer is owing to an innumerable multitude of small luminous worms or insects sporting in the waters. All the numberless species of animals which exist on the different departments of our globe are likewise infinitely diversified in their forms, organs, senses, members, faculties, movements, and gradations of excellence. As Mr. Addison has observed, "the whole chasm of nature, from a plant to a man, is filled up with divers kinds of creatures rising one above another by such a gentle and easy ascent, that the little transitions and deviations from one species to another are almost insensible. This intermediate space is so well husbanded and managed, that there is scarce a degree of perception which does not appear in some one part of the world of life." Here we have an evidence both of the infinite wisdom and intelligence of the Divine Being, and of his boundless goodness in conferring existence and happiness on such a countless multitude of percipient beings.

Since, then, it appears that every portion of matter in our world was intended for the support and accommodation of animated beings, it would be absurd in the highest degree, and inconsistent with the character of the Deity and his general plan of operation, to suppose that the vast regions of the planets, so exceedingly more expansive than our globe, are left destitute of inhabitants. Shall one small planet be thus crowded with a population of percipient beings of all descriptions, and shall regions four hundred times more expansive be left without one living inhabitant? Can the Deity delight to communicate enjoyment in so many thousands of varied forms to unnumbered myriads of sensitive existences in our terrestrial sphere, and leave the noblest planets of the system without a single trace of his benevolence? Can we suppose, for a moment, that while his *wisdom* shines so conspicuous in the mechanism of the various tribes of animals around us, no similar marks of intelligence are to be found in other regions of the universe? Such conclusions can never be admitted, unless we suppose that infinite wisdom and goodness have

been *exhausted* in the arrangements which have been made in relation to our world, or that the Great Source of felicity is indifferent about the communication of happiness.

As far as our observation extends, it appears that the material world is useless, except in the relation it bears to animated and intellectual beings. *Matter* was evidently framed for the purpose of *mind;* and if we could suppose that the vast masses of matter in the heavens had no relation to mind, they must, then, have been created in vain; a supposition which would derogate from the moral character and the perfections of Him who is "the only wise God." A superior nature cannot be supposed to be formed for the sake of an inferior. A skilful artist would never think of designing that which is of the greatest dignity, or which requires the utmost precision and the nicest mechanism, for the sake of the inferior part of his workmanship. He does not construct the wheels and pinions of an orrery for the sake of the handle by which they are moved, or of the pedestal on which the instrument stands; nor does he contrive a timepiece merely for the sake of the shell or case in which it is to be enclosed. In like manner, we cannot imagine that *man* was made for the sake of the brutes, or the inferior animals for the sake of vegetables, or the yearly production of vegetables for the relief and comfort of the soil on which they grow. This would be to invert the order of the universe, and to involve us in the most palpable absurdity. The order of things always *rises upward*, by gentle and regular degrees, from inanimate matter, through all the gradations of vegetable, animal, and immaterial existence, till we arrive at the Eternal and Incomprehensible Divinity. Hence it appears that the earth must have been formed, not for itself, but for the sake of the vegetable, sensitive, and intellectual beings it supports; and, by a parity of reasoning, the planets, most of which are much more spacious and more magnificently adorned, must have been formed and arranged for the sake of superior natures.

"Existence," as a certain writer has observed, "is a blessing to those beings only which are endued with perception, and is, in a manner, thrown away upon dead matter any farther than as it is subservient to beings which are conscious of their existence." Accordingly we find, from the bodies which lie under our observation, that matter is only made as the basis and support of living beings, and that there is little

more of the one than what is necessary for the existence and the ample accommodation of the other. The earth, as to amplitude of space, would contain a hundred times the number of animated beings it actually supports; and the ocean might perhaps contain thousands more than what are found amid its recesses; but, in such a case, they would not have free scope for their movements, nor experience all the comforts and accommodations they now enjoy.

From what has now been stated, it appears that the Divine Goodness is of so communicative a nature that it seems to *delight* in conferring existence and happiness on every order of perceptive beings, and, therefore, has left no part connected with the world in which we live without its inhabitants; and that no creature capable of feeling the pleasure of existence might be omitted in the plan of benevolence, there is an almost infinite *diversity* in the rank and order of percipient existence The scale of sensitive being begins with those creatures which are raised just above dead matter. Commencing at the polypus and certain species of shellfish, it ascends by numerous gradations till it arrives at man. How far it may ascend beyond this point is beyond the limits of our knowledge to determine. Had only one species of animals been created, none of the rest would have enjoyed the pleasures of existence. But in the existing state of things, all nature is full of enjoyment, and that enjoyment endlessly diversified, according to the rank and the percipient powers of the different species of animated existence. It would, therefore, be a reflection on the *goodness* as well as on the wisdom of the Divine Being, were we to suppose that no traces of Divine beneficence were to be found amid the expansive regions of the planetary globes. It would form a perfect *contrast* to the operations of Infinite Benevolence, as displayed in our terrestrial system, and would almost lead us to conclude that the same Almighty Agent did not preside in both these departments of the universe. But we may rest assured that the Deity always acts in harmony with his character throughout every part of his dominions; and, therefore, we may confidently conclude that countless multitudes of sensitive and intellectual beings, far more numerous and diversified than on earth, people the planetary regions.

From what has been stated on this subject, we may likewise conclude with certainty that the planetary worlds are

not peopled merely with animal existences, but also *with rational and intellectual natures.* For the scenes displayed in most of the planets cannot be appreciated by mere sensitive beings, nor are they calculated to afford them any gratification. Besides, if it be one great design of the Creator to manifest the glory of his perfections to other beings, none but those who are furnished with rational faculties are capable of recognising his attributes as displayed in his works, and of offering to him a tribute of thanksgiving and adoration. Such intelligences, we have every reason to believe, may far surpass the human race in their intellectual powers and capacities. There is an infinite gap between man and the Deity, and we have no reason to believe that it is entirely unoccupied. There is a regular gradation from inanimate matter and vegetative life through all the varieties of animal existence till we arrive at man. But we have no reason to believe that the ascending scale terminates at the point of the human faculties, unless we suppose that the soul of man is the most perfect intelligence next to the Divinity. If the scale of being rises by such a regular process to man, by a parity of reasoning we may suppose that it still proceeds gradually through those beings that are endowed with superior faculties ; since there is an immensely greater space between man and the Deity than between man and the lowest order of sensitive existence. And although we were to conceive the scale of *intellectual* existence above man rising thousands of times higher than that which intervenes between inanimate matter and the human soul, still there would be an infinite distance between the highest created intelligence and the Eternal Mind which could never be overpassed. It is quite accordant with all that we know of the perfections and operations of the Deity to conclude that such a progression of intellectual beings exists throughout the universe ; and, therefore, we have reason to believe that in some of the planets of our system there are intellectual natures far superior, in point of mental vigour and capacity, to the brightest geniuses that have ever appeared upon earth ; and in other systems of creation the scale of spiritual progression may be indefinitely extended far beyond the limits to which human imagination can penetrate. In the contemplation of such scenes of percipient and intelligent existence, we perceive no boundaries to the prospect ; the mind is overwhelmed amid the immensity of being, and feels itself

unable to grasp the plans of Eternal Wisdom, and the innumerable gradations of intelligence over which the moral government of the Deity extends; and, therefore, we may justly conclude that wonders of power, wisdom, and benevolence still remain for the admiration of intellectual beings, which the scenes of eternity alone can disclose.

Intellectual beings may likewise be distinguished into those which are linked to *mortal*, and those which are connected with *immortal* bodies. In the present state of our terrestrial system immortal bodies cannot exist. Had immortality been intended for man on earth, Infinite Wisdom would have adopted another plan; for the constitution of the earth, the atmosphere, and the waters, is not adapted to the support and preservation of immortal beings; that is, of those intelligences which inhabit a system of corporeal organization. From the reciprocal action of solids and fluids, of earth, air, and water, *life* results; and this very action continued, according to the laws which now operate, is the natural cause of *death*, or the dissolution of the corporeal system. But in other worlds a system of means may be adapted for preserving in perpetual activity, and to an indefinite duration, the functions of the corporeal machine which is animated by the intellectual principle; as would probably have happened in the case of man, had he retained his original moral purity and his allegiance to his Maker. Intelligent beings may likewise exist which are destined to pass from one state of corporeal organization to another, in a long series of changes, advancing from one degree of corporeal perfection to another, till their organical vehicles become as pure and refined as light, and susceptible of the same degree of rapid motion. The butterfly is first an egg, then a worm, afterward it becomes a chrysalis, and it is not before it has burst its confinement that it wings its flight, in gaudy colours, through the air. Man is destined to burst his mortal coil, to enter a new vehicle, and at last to receive a body "incorruptible, powerful, glorious, and immortal." Varieties analogous to these may exist throughout other regions of the universe. If there are not in nature two leaves precisely alike, or two trees, two cabbages, two caterpillars, or two men and women exactly similar in every point of view in which they may be contemplated, how can we suppose that there can be two planets or two systems of planets exactly alike, or that the corporeal organs and faculties of their inhabitants in

every respect resemble each other? Every globe and every system of worlds has doubtless its peculiar economy, laws, productions, and inhabitants. This conclusion is warranted from all that we know of the operations of the Creator; it exhibits, in a striking point of view, the depths of his wisdom and intelligence, and it opens to immortal beings a prospect boundless as immensity, in the contemplation of which their faculties may be for ever exercised, and their views of the wonders of Creating Power and wisdom continually extending, while myriads of ages roll away.

In the preceding pages I have endeavoured to illustrate the doctrine of a plurality of worlds, from the considerations that there are bodies in the planetary system of such *magnitudes* as to afford ample scope for myriads of inhabitants; that there is a *general similarity* among all the bodies of the system, which affords a presumptive evidence that they are intended to subserve the same ultimate designs; that, connected with the planets, there are *special arrangements* which indicate their *adaptation* to the enjoyment of sensitive and intellectual beings; that the *scenery of the heavens, as viewed from the surfaces of the larger planets and their satellites*, forms a presumptive proof of the same position; and that the fact that *every part of nature in our world is destined to the support of animated beings*, affords a powerful argument in support of this doctrine. These arguments, when viewed in all their bearings, and in connexion with the wisdom and benevolence of the Divine Being, may be considered as amounting to moral demonstrations that the planets and their satellites, as well as other departments of the universe, are the abodes of sensitive and intelligent natures. These, however, are not all the considerations or arguments which might be brought forward in proof of this position. Many others, founded on a consideration of the nature and relations of things, and the attributes of the Divinity, and particularly some powerful arguments derived from the records of Revelation, might have been stated and particularly illustrated. But I shall leave the further consideration of this topic to another volume, in which we shall take a survey of the scenery of the starry firmament, and of other objects connected with the science of the heavens.

On the whole, the doctrine of a plurality of worlds is a subject of considerable importance, and in which every rational being, who is convinced of his immortal destination, is deeply interested. It opens to our view a boundless prospect of knowledge and felicity beyond the limits of the present world, and displays the ineffable grandeur of the Divinity, the magnificence of his empire, and the harmonious operation of his infinite perfections. Without taking this doctrine into account, we can form no *consistent* views of the character of Omnipotence and of the arrangements which exist in the universe. Both his wisdom and his goodness might be called in question, and an idea of the Supreme Ruler presented altogether different from what is exhibited by the inspired writers in the records of Revelation. When, therefore, we lift our eyes to the heavens, and contemplate the mighty globes which roll around us; when we consider that their motions are governed by the same common laws, and that they are so constructed as to furnish accommodation for myriads of perceptive existence, we ought always to view them as the abodes of intelligence and the theatres of Divine Wisdom on which the Creator displays his boundless beneficence; for "his tender mercies," or the emanations of his goodness, "are diffused *over all his works*." Such views alone can solve a thousand doubts which may arise in our minds, and free us from a thousand absurdities which we must otherwise entertain respecting the Great Sovereign of the universe. Without adopting such views, the science of the heavens becomes a comparatively barren and uninteresting study, and the splendour of the nocturnal sky conveys no ideas of true sublimity and grandeur, nor is it calculated to inspire the soul with sentiments of love and adoration. In short, there appears to be no medium between remaining in ignorance of all the wonders of Power and Wisdom which appear in the heavens, and acquiescing in the general views we have attempted to illustrate respecting the economy of the planets, and their destination as the abodes of reason and intelligence. But, when such views are recognised, the bodies in the heavens become the noblest objects of human contemplation, the Deity appears invested with a character truly amiable and sublime, and a prospect is opened to immortal beings of a perpetual increase of knowledge and felicity, throughout all the revolutions of an interminable existence.

APPENDIX

PHENOMENA OF THE PLANETS FOR THE YEARS 1838, 1839.

For the sake of those readers who may feel a desire occasionally to contemplate the heavens and to trace the motions of the planetary orbs, the following sketches are given of the positions and motions of the planets for two years posterior to 1837.

POSITIONS, &c., OF THE PLANETS FOR 1838.

I. THE PLANET MERCURY.

This planet can be seen distinctly by the naked eye only about the time of its greatest elongation; and to those who reside in northern latitudes it will scarcely be visible, even at such periods, if it be near the utmost point of its southern declination.

The following are the periods of its greatest elongation for 1838: January the 3d it is at its *eastern* elongation, when it is 19¼ degrees *east* from the sun, and will be seen in the *evening* about thirty or forty minutes after sunset, near the southwest, at a little distance from the point where the sun went down. But as it is then in 20° 41′ of south declination, its position is not the most favourable for observation. Its next greatest elongation is on February 12, when it is 26° 10′ to the *west* of the sun, and will be seen in the *morning*, before sunrise, near the southeastern quarter of the horizon. April 25 it will again be seen in the *evening* at its eastern elonga-

tion, 20° 20′ east of the sun, when it is in 21° 43′ of north declination. It will be seen at this time about 15 degrees north of the western point of the horizon, almost immediately above the place where the sun went down. During five days before and after the time now specified there will be favourable opportunities for detecting Mercury with the naked eye or with a small opera-glass. On June 12 is its greatest *western* elongation, at which time it is 23° 5′ west of the sun, and is to be looked for in the *morning*, before sunrise, near the northeastern part of the horizon; but the strong twilight at this season will probably prevent it from being distinguished by the naked eye. Its next greatest *eastern* elongation is on August 23, when it is 27¼ degrees from the sun. It will be seen, for nearly an hour after sunset, a little to the south of the *western* point of the compass, and a few degrees above the horizon. It may be seen during ten or twelve days before the period here stated, and six or eight days after it. This will form one of the most favourable periods which occur throughout this year for observing Mercury. October 4 it will again be at its greatest *western* elongation, when it will be seen in the *morning* in a direction nearly due east. December 17 it is at its greatest *eastern* elongation, but its southern declination being then more than 24 degrees, it will set in the S. W. by S. point of the compass a few minutes after the sun, and will consequently be invisible to the naked eye.

The periods most favourable for detecting this planet in the *evenings* are April 25 and August 23; and in the *mornings*, February 12 and October 4. During the interval of a week or ten days, both before and after the time of the greatest elongation, the planet may generally be seen in a clear sky, when in such favourable positions as those now stated.

II. THE PLANET VENUS.

This planet will appear as an evening star during the months of January and February. About the beginning of January it will be seen near the southwest quarter of the heavens a few minutes after sunset. About the beginning of February it will set nearly due west. It will be visible in the evening till about the 25th of February, after which its nearness to the sun will prevent it from being distinguished. Throughout the whole of its course during these two months it will

appear of the figure of a crescent when viewed with a telescope, and the crescent will appear most slender about the end of February (see Fig. XII., p. 81). On March 5 it passes its *inferior* conjunction with the sun, after which it will be no longer seen in the evenings for the space of ten months. It then becomes a morning star; and, about eight days after its conjunction, will be seen in the *morning*, before sunrise, a little to the south of the eastern point of the horizon. From this period till near the middle of May it will appear of a crescent form. Its greatest brilliancy will be on April 10; its greatest elongation from the sun on May 14, when it will appear of nearly the form of a half moon, and its *superior* conjunction on December 18, soon after which it will again be seen as an evening star.

The brilliancy of this planet is such that it can scarcely be mistaken by any observer, especially when its position in the heavens is pointed out.

III. THE PLANET MARS.

This planet will not be much noticed by common observers till near the end of the year. About the beginning of March it is in conjunction with the sun, when it is farthest from the earth, about a month or two before and after which period it is scarcely distinguishable from a small star. From April to December it will be visible only in the *morning*, in an easterly direction; but its apparent size will gradually increase till the end of the year. It is distinguished from the fixed stars and from the other planets by its ruddy appearance.

IV. THE PLANETS VESTA, JUNO, CERES, AND PALLAS.

These planets are not perceptible by the naked eye. The best time for observing them with telescopes is when they are at or near the period of their opposition to the sun, when they are nearest the earth, and even then it will be difficult to detect them without the assistance of transit or equatorial instruments.

Vesta will be in opposition to the sun on the 29th December, its right ascension being $6^h\ 31'\ 47''$, and its declination $22°\ 4\ 1\text{-}2'$ north. At midnight it will be due south, at an elevation of 60 degrees above the horizon, in the latitude of

52 degrees north, about 15 degrees to the southwest of the star Pollux, and 7 1-2 degrees north of *Gamma* Gemini.

Juno is in opposition on the 17th June, in right ascension 17^h 46 1-2′, and south declination 4 1-2°. It will be on the meridian at midnight, at an elevation of 33 1-2 degrees above the southern horizon.

Neither *Ceres* nor *Pallas* will be in opposition to the sun during this year.

THE PLANET JUPITER.

This planet will make a very conspicuous appearance in the heavens during the winter and spring months. About the beginning of January it will rise, a little to the north of the eastern point of the horizon, a few minutes after ten o'clock in the evening, and will pass the meridian, at an elevation of 43 1-2 degrees, about half past four in the morning. About the middle of February it will rise about seven in the evening, nearly in the same direction, and will come to the meridian about half past one in the morning. During the months of January and February it will be seen either in the evenings or the mornings. About the middle of January it will be seen, in a southwesterly direction, about six o'clock in the morning. From the beginning of March till the end of August it will be seen in the evenings without interruption when the sky is clear. On the 22d September it is in conjunction with the sun, but it will seldom be noticed for a month before this period. During the months of November and December it will be again seen in the east, only in the morning, some time before the rising of the sun.

This planet can scarcely be mistaken, as it is next to Venus in apparent magnitude and splendour. It will appear most brilliant about the beginning of March, when it is in opposition to the sun, and its satellites and belts will present an interesting sight when viewed with a good telescope. At present (November 22, 1837), four belts, nearly equidistant from each other, are distinctly visible with a power of 200 times. Their appearance is very nearly similar to what is represented in Fig. LVI., p. 182, so that a considerable change has taken place in their appearance since last June, when they appeared nearly as in Fig. LII., p. 173. At that time the middle belt was the only one easily perceptible, while the other two, at

the north and south extremities, appeared extremely faint and obscure. At present all the four belts are distinctly marked.

VI. THE PLANET SATURN.

This planet passed its conjunction with the sun on the 12th November, 1837. From the beginning of the year till about the middle of April it will be visible chiefly in the mornings. On the first of January it will rise near the southeast, about twenty minutes past four in the morning, and will pass the meridian about forty-eight minutes past eight, at an elevation of 21 degrees above the southern horizon. On the first of April it will rise at half past ten in the evening, and about midnight will be seen near the southeast about 10 or 12 degrees above the horizon. From this period Saturn will be visible in the evenings till near the end of October, rising every evening at an earlier hour than on the preceding. On the 16th May it is in opposition to the sun, when it will rise near the southeast at half past seven, and come to the meridian at midnight. During the months of August, September, and October, it will be seen chiefly in the *southwest* quarter of the heavens after sunset, at a small elevation above the horizon. It will be very perceptible during September and October, on account of its low altitude at sunset. It will be in conjunction with the sun on the 24th November.

This planet is not distinguished for its brilliancy to the naked eye, though it exhibits a beautiful appearance through the telescope. It is of a dull leaden colour, and is not easily distinguished from a fixed star except by the steadiness of its light, never presenting a twinkling appearance as the stars do, and from which circumstance it may be distinguished from neighbouring stars. The best times for telescopic observations on this planet will be in the months of April and May, when its ring will appear nearly as represented in Fig. LXIII., p. 205.

VII. THE PLANET URANUS.

This planet is, for the most part, invisible to the naked eye. The best time for detecting it, by means of a telescope, is when it is at or near the period of its opposition to the sun, which happens on the 3d September. At that time it passes

the meridian at midnight, at an elevation of about 30⅓ degrees above the horizon. It is situated nearly in a straight line between the star *Fomalhaut* on the south and *Markab* on the north, being nearly in the middle of the line, about 22½ degrees distant from each. It is in the neighbourhood of several small telescopic stars. On account of its slow motion, its position in respect to the above stars will not be much altered for a month or two. On the 1st November it passes the meridian at eight o'clock in the evening. Its *right ascension*, or distance from the first point of Aries, is then $22^h\ 42'$, and its declination $9°\ 4'$ south.

N.B.—In the above statements the observer is supposed to be in fifty-two degrees north latitude. In places a few degrees to the north or south of this latitude, a certain allowance must be made for the times of rising, and the altitudes which are here specified. To those who reside in lower latitudes than fifty-two degrees, the altitudes of the different bodies will be *higher*, and to those in higher latitudes the altitudes above the horizon will be *lower* than what is here stated.

PHENOMENA OF THE PLANETS FOR 1839

I. MERCURY.

THE greatest *western elongation* of this planet happens on the 26th of January, when it is $24°\ 50'$ west of the sun. It will be seen near the southeast a little before seven in the morning. On the seventh of April, and a few days before and after it, it will be seen in the *evening* in a direction west by north. On the 24th of May it will be seen in the morning, in a direction a little to the north of the eastern point, before sunrise. Its next elongation will happen on the fifth of August, when it is twenty-seven and one third degrees distant from the sun. At this period, and a fortnight before and a little after, it will be seen near the west point, or a little north of it, about nine o'clock in the evening or a few minutes before it. This will be a favourable opportunity for distinguishing this planet with the naked eye. It will be again seen in the morning, about five o'clock, a little to the north of the east

point, on September 18. Its next greatest elongation will be on the 30th of November, when it will appear in a direction southwest by south about the time of sunset. This will be a very unfavourable position for attempting to distinguish Mercury. It passes its inferior conjunction with the sun on the 18th December.

II. VENUS.

This planet will be an evening star from the beginning of the year till 6th October, when it passes its inferior conjunction with the sun. It will not, however, be much noticed till about the beginning of March, on account of its nearness to the sun and its southern declination. It will appear most brilliant during the months of May, June, July, August, and beginning of September, when it will be seen at a considerable elevation in the western and northwestern quarter of the heavens a few minutes after sunset. About the middle of October, or a few days before, it will appear as a *morning* star near the *southeastern* quarter of the sky, and will continue as a morning star till the end of the year.

III. MARS.

During the months of February, March, and April, this planet will appear in its greatest lustre. It will be in opposition to the sun on the 12th March, at which period it is nearest to the earth, and will appear twenty-five times larger in surface than in the opposite part of its orbit. At this period it will rise about half past five in the evening, a little to the north of the *east* point, and will come to the meridian at midnight, at an altitude of forty-five degrees. It will be easily distinguished from the neighbouring stars by its size and its ruddy appearance. At this time the planet Jupiter will appear in a direction about twenty-two degrees southeast of Mars. From the month of May till the end of the year Mars will be visible in the evenings, but its apparent size will be gradually diminishing, and, on account of its southern declination, will not be much noticed after the month of September. On the 19th July, at forty-six minutes past nine o'clock in the evening, Mars and Jupiter will be in conjunction, at which time Mars will be one degree and a half to the south

of Jupiter. They will then be seen near the western point, at a small elevation above the horizon.

IV. VESTA, JUNO, CERES, AND PALLAS.

Juno arrives at its opposition to the sun on the 12th October, at $1^h\ 32'$ P.M. It passes the meridian at midnight, or at $12^h\ 2\frac{1}{2}'$, at an altitude of $34^\circ\ 21'$, and is then about twelve degrees west of the star *Mira*. Declination $3^\circ\ 39'$ south, and right ascension, $1^h\ 26'$.

Pallas is in opposition to the sun April 1, at $7^h\ 10'$ A.M. Right ascension $13^h\ 12'\ 42''$. Declination $14^\circ\ 21'$ *north.* It passes the meridian at midnight, at an elevation of $52^\circ\ 22'$. It will then be about fourteen degrees southwest from the bright star *Arcturus.*

Ceres is in opposition April 6, at $7^h\ 8'$ P.M. Right ascension $13^h\ 23'\ 40''$. Declination $7^\circ\ 54'$ *north.* It passes the meridian at midnight, at an altitude of nearly forty-six degrees. It will then be seen, by means of a telescope, at about twelve degrees southwest from *Arcturus.*

The planet Vesta is not in opposition to the sun this year.

V. JUPITER.

During the months of January and February this planet will be chiefly seen in the morning. On the 12th January it rises about midnight, a little to the south of the eastern point of the horizon, and comes to the meridian at forty minutes past five in the morning, at an altitude of about thirty-two degrees. On the 12th March it rises at eight in the evening, and will be seen near the southeast part of the heavens about eleven and twelve o'clock P.M. On the 3d April it is in opposition to the sun, when it rises about half past six P.M., and comes to the meridian about midnight. From this period it will form a conspicuous object in the evening sky till near the end of September. It arrives at its conjunction with the sun on the 22d October, after which it will be seen only in the morning throughout the month of December and the latter part of November. On the 20th March, at one o'clock in the morning, all the satellites of Jupiter will appear on the east, or right-hand side of the planet, *in the order of their distances* from Jupiter. The same phenomenon will

happen on August 1, at forty-five minutes past eight, and 20th September, at 7^h P.M.

VI. SATURN.

This planet will be visible only in the morning during the months of January, February, and March, and will then be seen towards the southern and southeastern parts of the sky. On the first of February it will rise, about half past two in the morning, near the southeast, and will come to the meridian at forty-nine minutes past seven, at an elevation of eighteen degrees above the horizon. On the first of April it will rise at forty-two minutes past eleven in the evening, and will pass the meridian a few minutes before four in the morning. It will be in opposition to the sun on the 29th May, when it will rise in the southeast at forty-five minutes past seven P.M., and will pass the meridian at midnight, at an altitude of eighteen and a half degrees above the southern point of the horizon. This will be a favourable opportunity for viewing its ring with good telescopes, when it will appear nearly in its full extent, as represented Fig. LXV., p. 205. From this period Saturn will generally be visible in the evening till about the end of October, when its low altitude and its proximity to the sun will prevent its being distinguished by the naked eye. About the middle of August, at nine o'clock in the evening, it will be seen near the southwest at a small elevation above the horizon. It will be in conjunction with the sun on the fifth December, after which it will be invisible to the naked eve till the beginning of 1840.

VII. URANUS.

This planet will be in opposition to the sun on the 7th of September, at 30 minutes past seven in the evening. Right ascension $23^h\ 4'$, or $346°$ east from the point of Aries, reckoned on the equator. South declination $6°\ 52\frac{1}{2}$. It will come to the meridian at midnight, at an elevation of $31°\ 8'$ above the horizon. At this time it is in the immediate vicinity of the star *Phi*, Aquarii. On the the 25th of August, at 20 minutes past one in the morning, it is in conjunction with this star, being only 15′, or one quarter of a degree to the north of it, at which time the planet and the star, if viewed

with a telescope of moderate power, will both appear in the field of view. The months of August, September, October, and November will be the most eligible periods for detecting this planet with the telescope. On the 1st of November it passes the meridian at 15 minutes past eight in the evening, at an altitude of $30\frac{1}{2}$ degrees.

N.B.—The preceding descriptions of planetary phenomena are chiefly intended to inform common observers as to the seasons of the year when the different planets may be seen, and the quarters of the heavens to which they are to direct their attention in order to distinguish them.

It may not be improper to observe, that the planets in general cannot be distinguished by the naked eye for about a month before and after their conjunctions with the sun, except *Venus*, which may frequently be seen within a week before and after its *inferior* conjunction. But this planet will sometimes be invisible to the naked eye for a month or two after its *superior* conjunction with the sun.

Should the above descriptions of celestial phenomena prove acceptable to general readers, they may be continued in future years.

INDEX.

A.

B.

C.

D.

E.

F.

G.

174

THE LIBRARY OF CONGRESS